The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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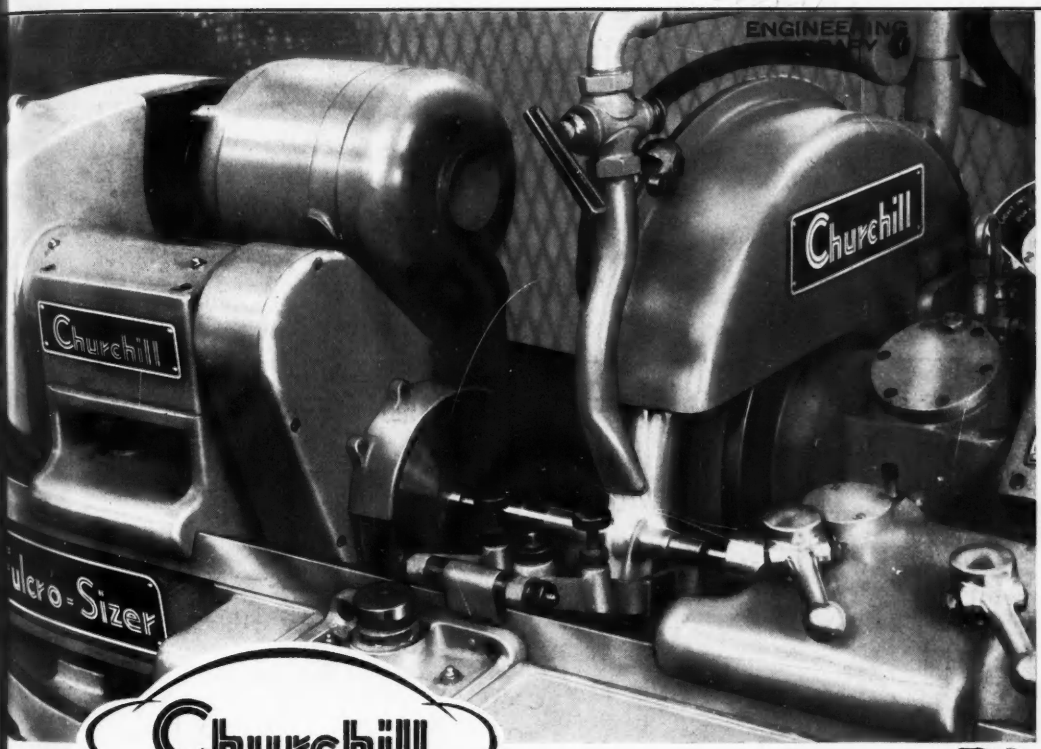

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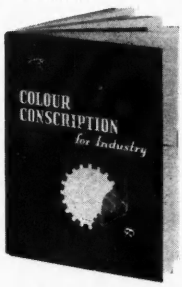

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *HARD-CARBIDE ALLOYS WITHOUT COBALT BINDERS*

A recent invention relates to a novel method of preparing alloys of hard carbides, in which the grains are not bound by any purely metallic cement, and in particular not by any metal of the iron group. It is claimed that these new alloys are highly resistant to abrasion, that they are compact and coherent, and that they include only small pores, which are smaller in number and in size than those of carbides containing cobalt. The method of preparation of these carbides consists of sintering compacts which are an intimate mixture of the refractory metal with a carbide of the same metal capable of forming a lower carbide. In this way a product will be obtained which comprises a carbide or a mixture of carbides not containing free metal. A typical example is the preparation of a mixture of tungsten with tungsten carbide, which by sintering is transformed into an alloy comprising a mixture of the carbides WC and W_2C, with a total carbon content of between 3 and 6%. Sintering of a compact containing 73·5% by weight of tungsten carbide and 26·5% metallic tungsten at 1800°C for 15 min yields a product of 1960 kg/mm² Vickers hardness, the mass being completely free from pores. This must be considered a remarkable result, since tungsten carbide alloys agglomerated with cobalt are sintered at a temperature much greater than the melting point of the eutectic alloy which cobalt forms with tungsten carbide. It is claimed that sand-blast nozzles made by the new process have a service life at least twice that of cast or sintered nozzles of any other type produced by conventional techniques. The process can also be used advantageously in many other ways.

• *IMPROVEMENTS IN GERMANIUM TRANSISTORS*

It is reported that the development of a new method of manufacturing transistors and other solid-state devices made from germanium has resulted in two improved types of transistor. One of these is capable of efficient operation at very high frequencies, while the other is a special type, called a photodiode, which is 10,000 times more sensitive to light than a conventional photoelectric cell, yet can control a hundred times more current. These transistors are of the *p-n-p* germanium junction type. Conventional methods of transistor manufacture rely on precise temperature control to obtain a product of consistent quality. A thin slice of *n*-type germanium is placed between two layers of metal and heated. The metal atoms dissolve through the germanium, forming two outside layers of *p*-type germanium and leaving a thin *n*-type layer between them. The thinner and the more uniform the *n*-layer, the better the performance of the finished transistor. Too high a temperature causes the thin layer of *n*-type germanium to melt away, and the transistor is spoiled, while too low a temperature leaves the *n*-layer too thick, giving poor transistor performance. It is claimed that, although the new process is carried out with the temperature practically uncontrolled, a product of greatly improved consistency is obtained. This new process is based upon the use of a cooling-off period during the heating of the transistor, so that the critical *n*-layer can be built up to the desired thickness and uniformity. It is claimed that these transistors can amplify pulses of frequencies considerably higher than those handled by conventional junction types. The second transistor type referred to, i.e., the new photodiode, operates on a voltage of either $1\frac{1}{2}$ or 6 V and is capable of operating a standard relay without the need for any amplification.

• *PISTON-RING MATERIAL FOR INTERNAL COMBUSTION ENGINES*

A new piston-ring material is proposed for internal combustion engines, especially compression-ignition engines, in order to make the piston rings more resistant to corrosive conditions, such as those arising from the use of fuel of high sulphur content. The inventors claim that, while it has been established that an aluminium-alloy piston with a cast-in austenitic ring carrier reduces very considerably the rate of wear on both the piston and the cylinder liner under corrosive conditions, its use involves a substantial increase both in weight and cost. In particular, such a ring carrier would often require rebalancing of the engine, to avoid an increase in torsional vibration and loss of power. It is therefore proposed to make the piston rings of aluminium bronze containing 5 to 15% aluminium, 2 to 8% nickel, 2 to 8% iron, and 0·25 to 8% manganese, the remainder being copper, with or without small amounts of tin, lead, and/or silicon. After heat treatment and

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tempering, these rings are claimed to be highly resistant to wear and to corrosion attack from fuel oils of high sulphur content. They may be chromium-plated either on the periphery or over the whole ring bearing surface, and are said to have the advantage that they can be carried directly in grooves formed in a normal aluminium-alloy piston, without excess wear being encountered when using sulphur-rich fuel or other fuels producing acid deposits in the cylinder. They are also suitable for use in compressors and pumps transmitting a variety of corrosive gases and liquids.

• *SILVER-BRAZED CYLINDER BLOCKS FOR AUTOMOBILE ENGINES*

A new method of manufacturing automobile-engine blocks has been developed and is expected to eliminate or drastically reduce the baked sand coring now used in engine-block construction. This method is based on a design in which the entire cylinders and top deck are not included in the casting of the block, but are a separate assembly. The centrifugally-cast iron cylinders are silver-brazed to a steel top deck and the unit is sealed to the block by a paper-neoprene gasket. The lower ends of the cylinders are sealed by rubber rings where they pass into the crank-case. It is claimed that the new design will result not only in a more durable engine, but that it also has many manufacturing advantages. Thus, larger cylinder diameters will be possible for given cylinder centre distances, while softer iron can be used in the block proper, permitting up to 25% more blocks to be machined on a given set of machine tools. Furthermore, better material can be used in the cylinders, and cylinder-wall thickness will be uniform and precisely controlled. It is expected that failure from water leaks and other defects will be reduced and that the cylinders in an engine of this design will not be subject to structural stresses. The design is also considered to be especially adaptable to die-cast aluminium blocks, which have been the subject of much research in the automobile industry.

• *THE EFFECT OF WATER ON THE STRENGTH OF STRUCTURAL PLASTICS*

Recent investigations have shown that the strength of polyester or epoxy glass-reinforced plastics is appreciably reduced by exposure to water. This weakening appears to result from deterioration of the resin, the glass, and the glass-resin bond. The manner in which water effects these changes is not yet understood but, since resins of many widely different chemical compositions are affected, it appears probable that the change in the resin is of a physical nature, with the water acting as a plasticizer or internal lubricant for the movement of the large resin molecules. In order to minimize the effect of water on reinforced plastics, many types of glass finishes or coupling agents have been developed, these being applied to the surface as very thin films. They are designed to provide active groups on each end of the molecule, bonding to the glass and to the resin to provide a more water-resistant bond than can be obtained by applying the resin directly to glass. Most of this work has been concerned with improving the properties of polyester resins, and reports on the relative wet strength of polyester-resin laminates made with various glass finishes indicate that considerable improvement has resulted. Little information is available on the effectiveness of finishes for use with other types of resins, and for epoxy resins no finish showing outstanding improvement has as yet been found, although it is reported that experimental chlorosilane glass finishes have given good results with epoxy and phenolic resins, as well as with polyester resins. There is no doubt that further research is required with regard to a suitable coupling agent to be applied to the fresh glass immediately after it is drawn into fibre.

• *PRESSURE WELDING OF ALUMINIUM FOIL*

A novel technique for the pressure welding of aluminium foil appears to hold considerable promise. According to the patent covering this process, it is intended to apply it to aluminium between 0·005 and 0·2 mm in thickness, either in sheet form as in aluminium foil or as a made-up product such as collapsible tubes. The process can also be used for the sealing of foil containers for packaging. It is well known that, in order to obtain a satisfactory weld in the case of aluminium, it appears essential to remove or break up the oxide film normally present on the surface of the aluminium. This is usually effected by scratching or abrading the surface to be joined but, in the case of aluminium foil having a thickness of less than 0·05 mm, the material is too fragile to permit this process to be used. In the case of unannealed aluminium foil a further difficulty is caused by the presence on the surface of the foil of rolling lubricants used in the production of the sheets. The new process is based on the observation that, when the welding of aluminium foil is effected at elevated temperatures ranging from 360 to 500°C and under suitable pressure, a good weld can be obtained without any pretreatment of the surface of the foil. However, in this temperature range, aluminium tends to coat the pressure-exerting elements and to stick to them. However, it has been found that, when these elements are made of carbon, "tinning" of these parts is avoided. The carbon to be used for this purpose may be a coarse- or medium-grain material of the type sometimes used in the production of carbon brushes and electrodes.

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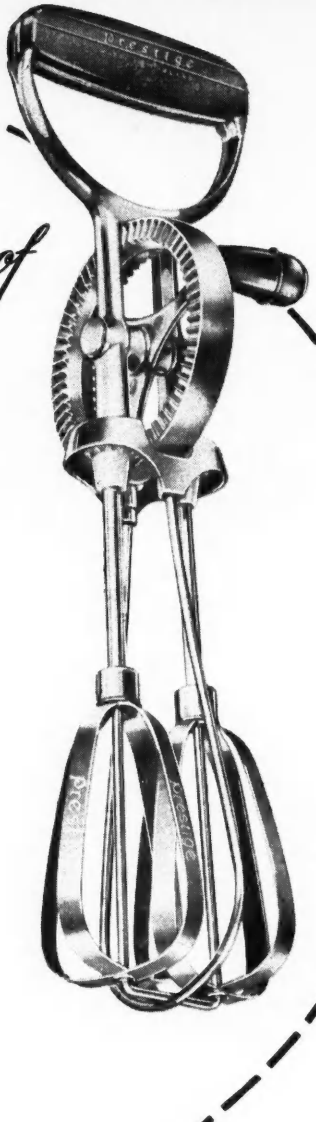

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• *ELECTRONIC RELAY FOR SELECTIVE AUTOMATIC SWITCHING*

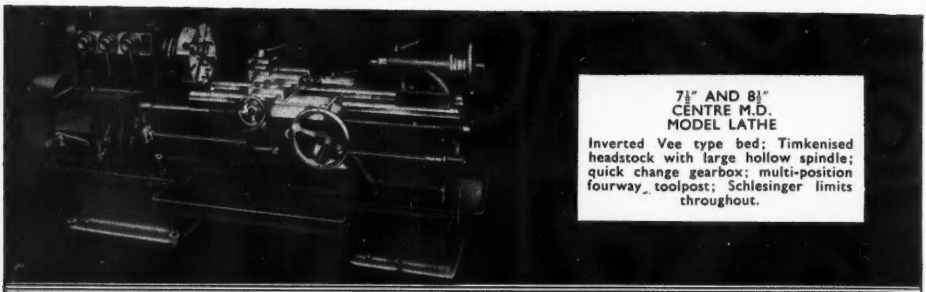
Selective automatic switching on any one of several electrical loads connected to the same power circuit can be accomplished by a novel design of electronic relay which requires no separate control-circuit wiring. Operated by dual-coded signals superimposed on conventional a.c. power circuits, these devices respond only to special combinations of pulse frequencies and pulse codes ; they were developed for the automatic control of electrical equipment from central control stations and are capable of distinguishing between any one of ten *on* and ten *off* codes on the same frequency. In design, the relays are made up of two basic units, i.e., a simple electronic receiver designed to accept only one signal frequency, and an electromechanical decoder which is sensitive to pulse codes. To operate these relays, a " start " pulse of the proper frequency and duration must first be received. As soon as such a pulse is detected by the receiver, it is passed on through a cold-cathode tube to a selection magnet which closes the decoder motor contacts, starting rotation of the decoding cup. If cup rotation is maintained for more than 2 sec, a motor cam closes a motor holding circuit and keeps it closed for one revolution, complete rotation of the cup requiring 60 sec. Then, 2 sec after the start-signal has been received, any one of ten 3-sec " circuit-selection " pulses detected during the next 50 sec will cause a selection magnet to attempt to pull a signal-contact lever into the decoder gate, and, if a proper pulse signal appears when this lever is aligned with the gate, the lever enters the gate and, with further rotation of the cup, cannot escape. The decoder cup continues to revolve and, during the final 5 sec of rotation, the signal-contact lever is further depressed and the signal contacts are closed.

• *EXPLOSION SUPPRESSOR WITH NYLON BELLOWS*

A new device for the sensing and suppression of incipient explosions relies on the use of nylon bellows. This suppression system was designed for use in jet-aircraft fuel tanks and is activated by a rate-of-pressure rise detector, in which the rise in pressure caused by the incipient stage of an explosion in a fuel tank compresses a bellows diaphragm fabricated from extruded nylon film. This in turn supplies current to a small detonator within a capsule containing a suppressant agent, generally bromochloromethane. When the detonator is fired, the suppressant is scattered as a mist, rendering inert the unburned vapours around the expanding flame front and stifling the explosion. Because of the time element involved, the response of the bellows must be virtually instantaneous. It is stated that, of all the materials tried, nylon was the only one found suitable for this application. The explosion-suppression system is based upon the fact that, in the initial stages of any explosion or fire, the rise in pressure is not instantaneous, but occurs over a period of perhaps 3 to 4 millisec. During this brief time interval suppressants can effectively damp out the explosion before it causes damage. The main problem, therefore, was to find a bellows material which would not only be sufficiently sensitive to operate within the prescribed time, but which would also not deteriorate in the presence of fuel vapours. It is reported that systems of this type are already in use and are providing effective protection against the danger of explosion in jet aircraft. They have also been used in a number of industrial applications, their use being recommended in high-speed printing presses, flour mills, and in other cases where hazards due to explosive atmospheres exist.

• *BORON NITRIDE CERAMIC MATERIAL*

A new ceramic material, consisting of 56·4% nitrogen and 43·6% boron, is claimed to have a unique combination of properties which should make it suitable for many applications at temperatures up to approximately 3000°F., and higher temperatures in special cases. Possible applications specifically mentioned in the original report are rocket nozzles, crucibles for melting reactive metals and salts, combustion-chamber liners, bearings and bearing components, gaskets, equipment for handling molten glass, and pump parts for handling certain molten metals. The crystal structure of pure boron nitride consists of flat platelets which slip easily over each other, thus providing a lubricating effect. The material is usually hot-pressed into a dense form or is combined with metallic or non-metallic powders to form a variety of new materials, the hot-press process yielding an easily machinable, ivory-like form. Paradoxically, the material has a resistance to sand-blast erosion equivalent to that of plate glass, but its machinability is about the same as that of graphite. At low temperatures, hot-pressed boron nitride is said to be stronger than most refractory materials; it exhibits the same strength up to about 650°F. Between 650 and 1300°F its strength decreases rapidly, although above 1400°F the rate of strength loss decreases. As the result of a partial crystal orientation during hot-pressing, the material shows a directionalism in both compressive and transverse strength characteristics, this directionalism being marked in the case of thermal expansion. Tests are reported to indicate that there is ten times as much expansion in a direction parallel to the pressing force as there is perpendicular to it, when the material is heated to 1800°F.



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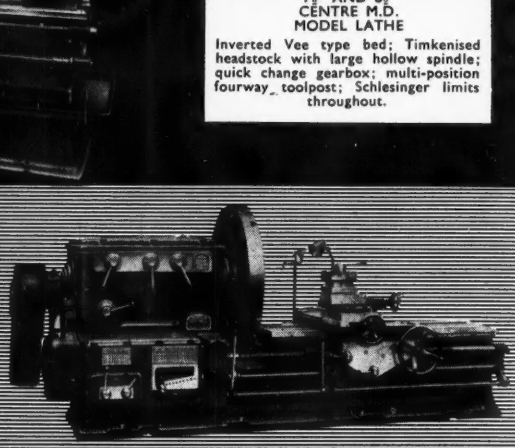

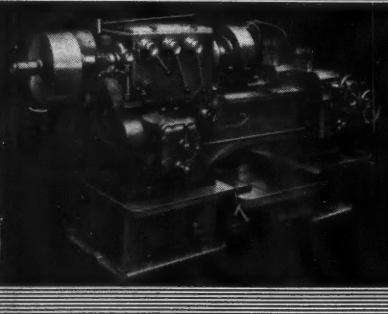

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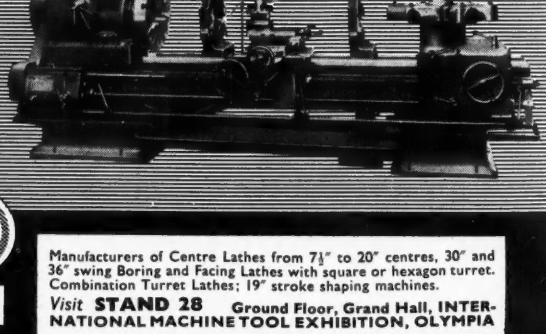

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• *SPRAYED METAL-OXIDE COATINGS*

It has been discovered that a tenacious coating of stable metal oxide, e.g., alumina, zirconia, or spinel, can be produced on metal or graphite, and on certain other substances, by using a spray gun in which a solid rod of the oxide to be applied is exposed to a high-temperature blast of gas to fuse the oxide. The gas then atomizes the molten oxide, so that it can be sprayed onto the metal or graphite. No preheating of the article to which the coating is to be applied is required. The small-diameter rods used are made by taking finely divided oxide material and providing a temporary binder. After moulding, the rods are sintered, the temporary binder being burned out in the sintering process. It is claimed that any kind of metal can be coated with the new method, but it is recommended that the metal surface be sand-blasted prior to coating, especially in the case of cast iron and steel. Coatings of any thickness can be produced by this process, which can also be used on ceramic materials. Thus, for instance, crucibles can be made more refractory and less pervious by coating them with a pure refractory oxide such as alumina or zirconia. Bricks can also be made more resistant to corrosion by hot gases in the same way. Sintered oxide material can itself be coated with the same or with a different oxide. Another important application appears to be the coating of gas-turbine blades. For this application stabilized zirconia containing 3 to 6% of lime is recommended.

• *PIPE WELDING WITH CONSUMABLE INSERTS*

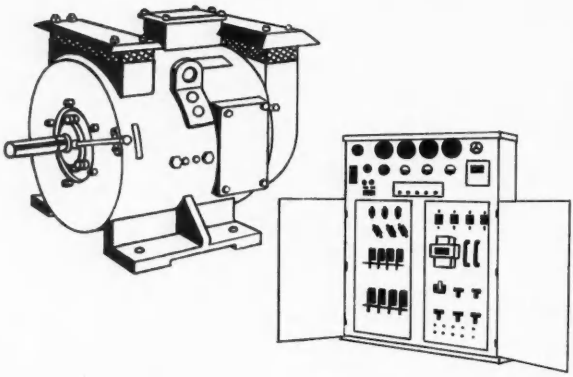
In piping systems for handling radioactive fluids in atomic reactor plants a completely reliable root-pass welding technique is essential. Corrosion attack in crevices or in weld-metal cracks or fissures could cause the shut-down of equipment, and repairs might not be possible until the level of radioactivity was sufficiently low to allow access. A consumable-insert method of root-pass welding is now available and appears to represent a significant step towards the solution of this problem. The filler metal or insert used is furnished in the form of a wire of special cross-sectional shape and can be made into rings which fit closely the internal pipe or tube diameter. Where joints of the highest quality are required, the pipe ends should be prepared by machining. Flame-bevelling and light surface-grinding has also been found to be a suitable preparation method for many applications. To obtain welds of the highest quality, purging with inert gas is recommended; in this connection, argon appears to be best for stainless steel. To avoid the necessity of purging the entire piping system, metal discs with rubber gaskets can be used to isolate the section to be welded. An inert-gas tungsten-arc torch is used to weld the root pass. At the start of welding the heat of the arc first fuses the top surface of the insert; the high surface-tension force existing on the barely molten internal surface, as compared with that under the arc, then causes the metal to flow radially outwards towards the arc, so that the completed root-pass joint is almost flush with the pipe wall and has an internal contour which is smooth and uniform and which causes a minimum of flow restriction.

• *SPRAY-METALLIZED LIGHT-METAL BEARINGS*

It has been found that the physical properties of sprayed metal coatings, e.g., their porosity, which enables such coatings to store lubricant, make them suitable for use in anti-friction bearings. Research has been undertaken for the purpose of establishing the correlation between the conditions of formation of sprayed coatings and their structure, which in turn govern their bearing properties. From the results obtained it is concluded that increased porosity tends to reduce the load capacity of the bearing, insofar as hydrodynamic friction is concerned. The majority of the pores are believed to form a communicating system of microcavities over the entire surface of the bearing. The porosity is largely governed by the ratio of oxygen to acetylene in the spray gun. The load capacity of the bearing was found to be inversely proportional to the thickness of the metal coating, and, taking into consideration the effects mentioned above, it is stated that the load capacity of sprayed bearings is equivalent to that of solid surfaces. Furthermore, their capacity of adjusting themselves to the journal is distinctly superior. On the basis of results of investigations into the geometry of bushings, recommendations are given concerning the form of bearing believed to have both high load capacities and satisfactory oil-storing properties when the bearing is expected to operate with critically reduced lubrication. Spraying of a hard alloy is reported to produce a more flexible bearing surface, although the overall value of the load capacity of a solid bearing is still higher. Attempts at simultaneous spraying, using two guns, of a hard and a soft metal proved to be unsuccessful. It is stated that severely damaged bearings of the sprayed type, after a subsequent short run-in, adjusted themselves so well that they regained the same values associated with undamaged bearings.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

Electro Dynamic-Special Equipment



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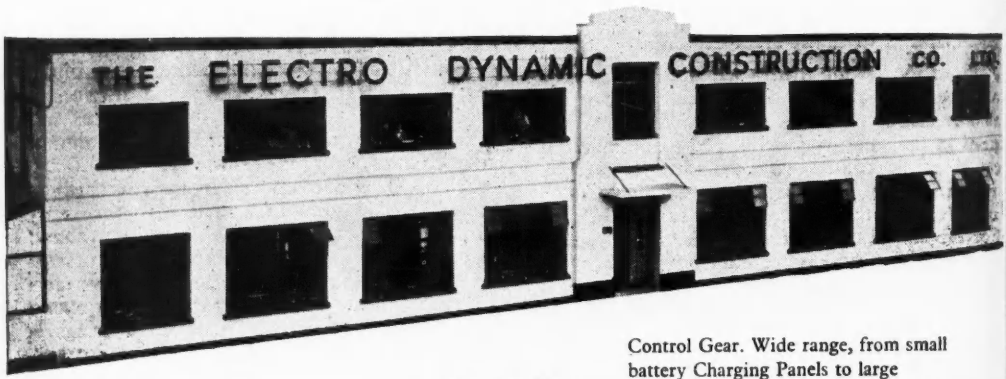

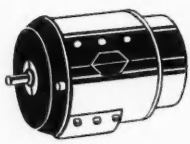

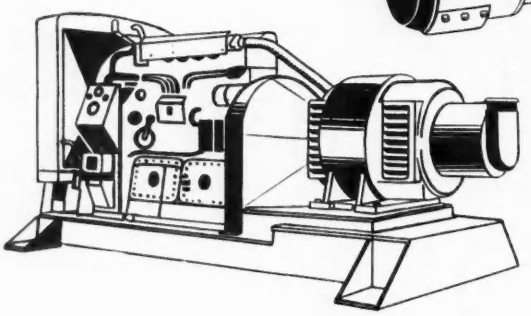

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Technical and Scientific Training in Russia

By N. H. POLAKOWSKI. (From *Metal Progress, U.S.A.*, Vol. 69, No. 1, January 1956, pp. 68–72, 3 illustrations.)

THE methods employed and the results achieved by Russia in training her engineers and scientists have recently received considerable attention, and the subject has been debated from various angles in both the technical and non-technical press. However, these articles have given general information rather than satisfying the professional curiosity of a specific category of technical men. It is the purpose of this article, which is based on material from various sources, ranging from the official Great Soviet Encyclopaedia to Russian and satellite periodicals, to bring out and emphasize such aspects of the technical and scientific training of manpower in the U.S.S.R. as may be of particular interest to engineers and teachers.

Insofar as Russian secondary education in elementary science is concerned, it may be said that a graduate of a full 10-year Russian secondary school is probably better equipped than his American counterpart graduating from junior high school, but not as well equipped as a holder of a British higher school certificate. Gold or silver medals are bestowed upon the two top ranking graduates—a practice which was universal in the Tsar's time and which was revived not so long ago by the present régime.

Since the number of candidates competing for entrance into institutions of higher learning has far exceeded the number of available places, students are usually accepted on the basis of competitive entrance examinations. Only medal-holders are normally exempted from this requirement and are admitted directly.

Graduates of secondary technical schools ("Technikums") are admitted to a university only after spending at least three years on an industrial assignment. Again, the above restriction does not apply to gold and silver medallists.

UNIVERSITIES AND INSTITUTES

There are 31 universities in Russia, which, from the viewpoint of organization, resemble the Central-European type and do not provide any engineering courses. They correspond somewhat to liberal arts colleges in the American scheme of things, but the normal duration of studies in all departments is five years.

Higher technical education is provided by two types of schools, as follows:—

(1) The large polytechnic institutes offering a choice of all-round courses in most of the major branches of engineering, such as civil, electrical, mechanical, and metallurgical. Here, the possibilities for specialization are usually limited to a selection among a few elective subjects during the senior years.

(2) Smaller specialty establishments, also termed "institutes", but adapted strictly to the needs of a particular industry. Thus, there are Institutes of Road Transport, Agricultural Chemistry, Medicine, Mining, Textile Industry, and so on. These are in turn split up into faculties, sometimes up to five in number, which turn out future experts in specific lines.

The great majority of Society specialists come from schools of the latter type. Originally, these institutes were run by the various Ministries for which they prepared personnel. However, since 1946 most of them were placed under the jurisdiction of a special Ministry of Higher Education, which in turn was merged in the spring of 1953 with the newly formed Ministry of Culture.

After the 10-year secondary school (or the 11-year course leading to a technician's diploma, plus three years of shop training) it takes 5 years to obtain an engineer's degree. In these 5 years the programme provides 36 hr per week of lectures and laboratory during the entire 5 years. The first two years are almost entirely devoted to fundamental sciences like mathematics, physics, chemistry, or applied mechanics. Basic professional subjects are taught in the third and part of the fourth year, the course culminating in a number of special disciplines and a thesis.

The curricula of similar faculties in various schools are standardized but, despite this fact, degrees obtained in certain institutes carry more prestige than others. In this respect, establishments which are authorized to accept and consider dissertations for a doctorate have the highest rating.

METALLURGICAL INSTITUTES

Apart from the metallurgical departments in some of the larger polytechnics (Leningrad and Sverdlovsk), there is a number of institutes specifically devoted to metals located in the principal metallurgical centres like Moscow, Dnepropetrovsk, or Magnitogorsk. Some of these evolved from metallurgical faculties of the old mining institutes, while others were specially built.

The Moscow Steel Institute, for instance, originated in 1930 from the metallurgical faculty of the old-established Moscow School of Mines. At present it has three faculties, as follows:—

(1) Metallurgical, with specialization in blast-furnace practice and steelmaking, electrometallurgy of steel and ferro-alloys, furnace design and controls, and foundry practice.

(2) Technological, with an emphasis on primary mechanical working, heat-treatment procedures, and powder metallurgy.

(3) Physico-chemical, where the main subjects are metal physics, physical chemistry of metallurgical processes, and corrosion.

Only one out of five applicants is admitted to this institute, where, incidentally, women represent one fifth of the student body. The school has a substantial

staff headed by 30 professors, and has well-equipped laboratories.

Other metallurgical institutes are similarly subdivided. For example, the Kalinin Institute of Non-ferrous Metals and Gold in Moscow, established in 1930, has five faculties, i.e., geology and prospecting, mining, metallurgy, technology, and administrative and industrial engineering.

Many of the larger institutes also provide night schools and correspondence courses. There are also three special institutes for full-time employees of steel mills. In these the duration of a degree course is six years with 17 to 18 hr of lectures and laboratory periods per week. In one of these institutes the percentage of female students was as high as 30%.

Graduate Studies and Advanced Degrees

There are no graduate schools in Russia of the type common in America. A holder of an initial degree can become a graduate student ("aspirant") by competitive examination in the subject in which he intends to specialize, one foreign language, and—not least—proficiency in political matters. Aspirants are attached to Chairs rather than departments. They attend virtually no lectures and pass only one test during the three-year period provided to carry out preliminary studies, the experimental work, and writing the thesis. The final examination is held in public and, apart from demonstrating competence in his main field of study and research, the aspirant also has to defend his dissertation against two opponents—a common procedure in continental Europe. If he is successful, he obtains the degree of "Candidate of Technical Sciences". His degree is substantially equivalent to an American Ph.D. In Russia a doctor's degree requires at least two additional years of thesis research.

As indicated earlier, not all the institutions are entitled to grant advanced degrees. Out of the 900 establishments for higher learning, a quarter of which are technical, only one-third has this privilege. However, "Candidates" are also turned out by more than 200 industrial and scientific non-teaching research institutes. In effect, then, there are about 500 institutions producing Soviet Ph.D.s and about 160 sources of "full" Doctors of Technical Science.

In order to prevent laxity and "liberalism" from creeping into the degree-granting institutions, as well as to enforce uniform standards, a Higher Attestation Commission is active within the Ministry of Culture. All advanced degrees to be conferred by any institution are first submitted to this commission for approval and are invalid without it. It appears, however, that this body is primarily concerned with doctorate dissertations. In 1952 it vetoed 121 Candidate degrees (about 2·5% of all submitted for confirmation) and 65 doctorate degrees (13% of the total).

Selective Recruitment from Industry

Since early 1941, Soviet citizens have been deprived by decree of any possibility of changing their jobs at will. As a rule, a man cannot leave his post without the specific consent of his employer; if he does, he is automatically liable to prosecution.

The law leaves, however, two exit possibilities, of which one is particularly pertinent to the subject matter of this article. An employer is bound to give a paid leave of absence and travelling expenses to any employee who has a university degree and who wishes to attend an examination for admission to advanced or graduate study. Acceptance of the individual as an "aspirant" automatically terminates his previous employment.

This system results in a steady influx into research establishments and advanced technical schools of men who frequently have had considerable practical experience before undertaking a three- or five-year course of graduate work. Such people represent a valuable asset to the institutions they eventually join, by combining theoretical knowledge with a down-to-earth engineering outlook.

The enormous appeal of an engineering or scientific career to Soviet youth has been variously interpreted by Western commentators. Naturally, there are always some students who choose technology as a career because of genuine interest. However, economic considerations usually provide a very large, if not the most powerful, stimulus. From this angle, and under the particular conditions prevailing in the U.S.S.R., the engineer or the applied scientist is on the top of a small world. His average salary may be as high as $1500 per year; in exceptional cases it may reach the $3000 mark, these estimates being based on the actual purchasing power of the rouble. While these figures may seem low, especially by American standards, such incomes nevertheless place the technical professions in Russia well ahead of physicians and lawyers. Holders of advanced degrees have the added opportunity of being eligible for positions in universities and research institutes, where not only are the salaries relatively high but also the work is congenial and the atmosphere is more relaxed than in industrial plants.

Achievements and Problems

Obviously, Russia has had notable success in building, in a relatively short period, an extensive training apparatus for the mass production of technicians and scientists of all descriptions and calibres. That these men are of good quality can be judged not only from percentage statistics showing continuous industrial expansion but also from the emergence of such tangible articles as nuclear weapons and intercontinental bombers. However, Soviet technical education is primarily designed to supply supervisors of manufacturing routine—and, it may be added, product engineers. As a result, many of the major technical developments on this side of the Iron Curtain appear in Russia shortly afterwards.

From opinions expressed from time to time in the Russian press, the inference can be drawn that this deficiency in their engineering educational system is appreciated—at least in some quarters. These criticisms are mainly concerned with the teaching programmes and textbooks now in use. The large number of narrowly specialized subjects which fill the curriculum is being attributed, not to a genuine concern with the students' needs, but to the necessity for staff members to fulfil the "norm", the minimum teaching load. It has also been pointed out that overburdening the student with a multitude of secondary details and a mass of factual data is likely to narrow his outlook and seriously impair his creative ability.

The most conspicuous feature of Soviet publications which have been approved as university textbooks is their huge size. Yet, upon examining them, the reader frequently finds a series of meticulous descriptions of phenomena, processes, and apparatus which appear to be only loosely interrelated, if at all. The overall picture

(*Concluded on page* 116)

Problems of High-Speed Cam Drives and Spring Surge

By M. FELDINGER. (From *Forschung auf dem Gebiete des Ingenieurwesens*, Edition "A", Vol. 21, 1955, Nos. 5 and 6, pp. 159–163 and 181–188, 14 illustrations.)

The timing gear of valves and fuel pumps for internal combustion engines incorporates cam drives, which are associated with difficulties in design, particularly when space is limited and high running speeds are required. This article considers design factors and some practical methods of cam design which avoid the occurrence of spring surge.

A CAM-OPERATED system can be reduced to a basic arrangement consisting of (a) a cam, (b) a mass assumed to be rigidly connected to the follower actuated by the cam, and (c) a spring coupled to the mass and rigidly attached at its other end.

The forces acting on the mass are the spring force P_s, the inertia force P_i of the mass itself, and the cam contact force P_c. The frictional force and the force due to gas pressure can, in most cases, be neglected. Equilibrium exists if $P_s + P_i + P_c = 0$.

Contact between the cam and follower is maintained as long as the cam contact force is positive or zero. At the upper speed limit N_{max}, the cam force is zero at one point at least on the cam contour. To remain on the safe side, the calculation is made assuming that the valve is acted upon by a force P_g equal to the gas pressure ahead of the valve [1] (i.e., this force is subtracted from the cam pressure force). Loss of contact is dangerous, since it gives rise to severe impact stresses.

First of all, particular care should be given to the driving arrangement ahead of the cam. The angular velocity should be constant and the camshaft should be free from torsional and bending vibrations or other cyclic irregularities of motion. If there is any vibration in the camshaft, of amplitude $\pm\varphi$ [radians] and frequency F_0, the upper speed limit is reduced to a lower permissible value N_{max}' and relative loss in speed range is

$$(N_{max}—N_{max}')/N_{max} = \varphi F_0/N_{max}.$$

To make full use of the available spring force in the region of negative accelerations, it is convenient to design the cam contour so that the lift curve y as a function of the cam angle φ is a portion of a cosine curve.[2]

SPRING VIBRATIONS

The forced motion of one end of the spring which follows the cam-lift curve $y(\varphi)$ gives rise to spring surge under certain conditions, i.e., to resonant vibrations of the coils of the spring in the direction of the spring axis. There are various possible "modes" of spring vibration, but in general only the fundamental mode is the one to be considered. In this mode of vibration, the ends of the spring remain stationary relative to the adjacent masses and the surge reaches its maximum amplitude at the middle coil (antinode) of the spring.

The excitation of the spring is due to the fact that the cam-lift curve can be represented as a Fourier series

$$y = (a_0/2) + \sum_{n=1}^{\infty} (a_n \cos n\varphi + b_n \sin n\varphi) \quad .. \quad (1)$$

where φ is the cam angle and n the order of the (Fourier) harmonic. The entire series of "forcing terms" is associated with the differential equation of motion[2,3] of the spring, i.e.,

$$\frac{\partial^2 u}{\partial t^2} + 2\gamma \frac{\partial u}{\partial t} - a^2 \frac{\partial^2 u}{\partial x^2} = 0 \quad .. \quad .. \quad (2)$$

where u is the displacement of a spring element from its neutral position in the x-axis direction (u being at a distance x from the stationary end of the spring), t is time, γ is the non-dimensional damping coefficient of the spring material, and a is the propagation velocity in the x-direction of compression waves in the spring coils. Eq. (2) is also affected by each individual pair of terms $a_n \cos n\varphi + b_n \sin n\varphi$ of the same nth order in eq. (1), so that surge can be caused by each of these harmonic orders. For the lowest mode, the vibration frequency is

$$F_0 = a/2L$$

where L is the length of the preloaded spring. (For other modes $F = ma/2L$, with $m = 2, 3, \ldots$, but these are not generally of importance.) The damping term is negligibly small and does not affect the frequency F_0. The vibration amplitudes of the nth order, with zero damping in eq. (2), are obtained as

$$u_n = U_n \sin (n\omega x/a) \times \sin n\omega t$$

where $U_n = \sqrt{(a_n^2 + b_n^2)}/\sin (n\omega L/a)$

and $\omega = 2\pi F_0$ [rad/sec]. The peak amplitude depends on the spring damping.

The stresses in the coils of the spring are magnified by the additional displacement due to surge. Let τ_s = "static" cyclic stress due to the compression of the spring at the total cam lift Y_s. The vibratory stress superimposed on this is

$$\Delta\tau_n = (\tau_s \pi\ Y_n)/Y_s \quad .. \quad .. \quad .. \quad (3)$$

where Y_n = maximum double amplitude or "total swing" of the middle coil when the spring is excited by a resultant harmonic $\sqrt{(a_n^2 + b_n^2)}$ of the nth order. The true "dynamic" stress is then $\tau_s + \Delta\tau_n$.

The contact force under conditions of surge is

$$P_{s\ max} = P_{s0} + kY_s + \Delta P_n \quad .. \quad .. \quad (4)$$

where P_{s0} = static preload, k = spring "rate" (stiffness), Y_s = total lift of cam, and ΔP_n = additional contact pressure force of the nth order due to surge. Eq. (4) gives the peak value; for intermediate points $y(\varphi)$ on the cam contour, Y_s should be replaced by the corresponding "static" displacement y, and ΔP_n becomes $\Delta P_n \sin \{n(\omega t + \alpha_n)\}$, where α_n = phase angle of ΔP_n.

Owing to the small amount of damping, a considerable change of phase angle α_n occurs with a very small variation in speed in the vicinity of the surge speed N_{res}. This is evident in the recordings shown in Fig. 1, the change in phase becoming marked in Figs. 1d, 1e, and 1f, which are on both sides of the resonance peak.

These oscillograms were taken with a load-cell type of pressure pick-up located at the stationary end of the spring for convenience and in order to avoid vibrating leads and connections. The pick-up thus measured forces corresponding to the strains, which have maximum values at the nodes (fixed ends) of the spring. The strains at these two end positions are in antiphase during the vibration; hence, in considering Fig. 1, it should be noted that the ripples or waveforms due to surge and denoted by c should in fact be reversed in the diagrams, in assessing

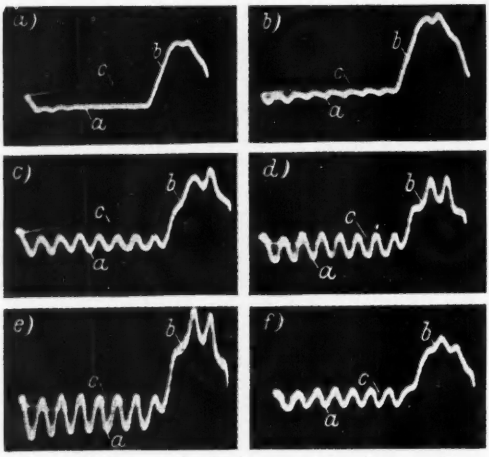

Fig. 1. Oscillograms of spring force recorded against cam angle. a = zero-circle portion; b = lift region; c = "flyback" of oscilloscope trace. The speeds $N_{a,b,c,d,e,f}$ at which these figures were recorded correspond to the flank amplitude of the resonance curve in Fig. 2.

them as forces acting on the oscillating mass, in addition to the cyclic force b (Fig. 1a) due to the cam lift. In view of this rapid change in phase, it is advisable to assume that the surge amplitude c (taken from Fig. 1d) is added arithmetically to the amplitude of the force (and stress) due to the cam-lift portion (b, in Fig. 1a) throughout the range of surge speed. The speeds $N_{a,b,c,d,e,f}$ at which the recordings in Fig. 1 were taken correspond to "flank amplitudes" of the resonance curve. This resonance curve is plotted in Fig. 2.

Now, for a fixed value of maximum permissible stress, the surge-free spring can have a preload, say, P_{s0}. The spring under conditions of surge has an additional dynamic pressure ΔP_n. To maintain the same maximum stress value, it would be necessary to reduce the preload to $P_{s0}' = P_{s0} - \Delta P_n$. Hence, the maximum surge amplitude denoted by a in Fig. 1e is decisive in calculating conditions with spring surge in the operating range.

Reverting to the equilibrium equation $P_s + P_i + P_c = 0$ and remembering that the limiting speed N_{max} is determined by the condition that the cam pressure P_c is zero at one point of the cam contour, it will be seen that, if the preload is lowered, the inertia force P_i will have to be reduced correspondingly. The upper speed limit is thus reduced to a new value N_{max}'. As the inertia forces are proportional to the square of the speed,

$$N_{max}'/N_{max} = \sqrt{P_s'/P_s} = \sqrt{1-(2\Delta P_n/P_s)}$$

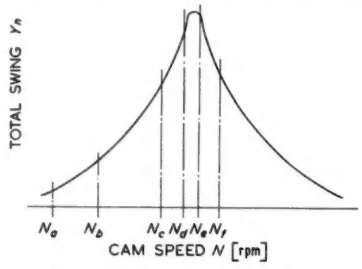

Fig. 2. Resonance curve of spring surge.

where P_s and P_s' are the spring forces which determine the limiting speeds N_{max} and N_{max}' (Fig. 3). As spring load P_s and stress τ are proportional and, owing to eq. (3),

$$2\Delta P_n/P_s = \Delta\tau_n/\tau_s = \pi Y_n/Y_s$$

and with $P_s = kY_s$, this gives $2\Delta P_n = \pi k Y_n$, so that the relative loss in speed range is

$$r = (N_{max} - N_{max}')/N_{max} = 1 - \sqrt{1-(\pi k Y_n/P_s)}.$$

For example, if $k = 20$ kg/cm, $Y_n = 0{\cdot}2$ cm, and $P_s = 20$ kg (values for a fuel injection pump), the relative reduction in the speed range, due to surge, is $r = 0{\cdot}39$, or 39%.

Influence of Disturbances on Spring Surge

The "disturbances" of the entire system associated with the cam, i.e., camshaft vibrations, play in coupling members, backlash of valve mechanism, etc., introduce further harmonics which act as additional excitation forces. If at any point $y(\varphi)$ the cam lift is modified by a disturbance Δy to a value $y + \Delta y = y'$, the new harmonics are

$$a_n' = a_n + \Delta a_n = (1/\pi)\int_0^{2\pi} (y + \Delta y)\cos n\varphi \, d\varphi \quad \text{and}$$

$$b_n' = b_n + \Delta b_n = (1/\pi)\int_0^{2\pi} (y + \Delta y)\sin n\varphi \, d\varphi,$$

for the nth order. Hence, even if the cam contour had no nth harmonic in the speed range considered, the presence of an nth order disturbance would still result in spring surge at the nth order critical speed.

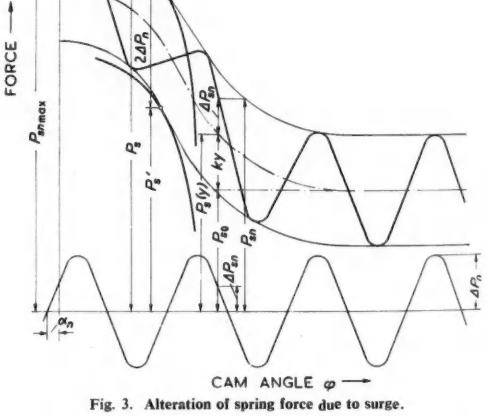

Fig. 3. Alteration of spring force due to surge.

The extent to which conditions of surge are affected by such disturbances was investigated by examining the effect of bending vibrations of the fuel-pump camshaft of a single-cylinder engine. Particular attention was given to proper alignment of the coupling and there was no play between the coupling members, so that any disturbances were due only to the bending vibrations of the camshaft. The resonance curves of the middle coil of the spring were determined for criticals of the orders 12 to 20. Separate measurements were taken for the portion of the engine cycle corresponding to zero-load conditions and the portion during which pump discharge occurs, i.e., when there is a sudden impact loading of the camshaft. The resulting curves showed different values for

both flanks and peaks, particularly for the high-speed criticals of low-order numbers. The differences are between 20% and 50% in amplitudes, the higher values being those corresponding to surge conditions during pump discharge.

The effect of play in the coupling members was also investigated by providing a gap corresponding to a cam angle of about 1·75 deg. It had no appreciable effect during the zero-load portion of the cycle, presumably because the angular gap was not taken up sufficiently rapidly to cause a disturbance at high running speeds, owing to the satisfactory mass balance of the cam drive. During pump discharge, however, each delivery stroke causes a powerful torsional impact, which accelerates the rotation through the angle of the gap. Under delivery conditions, therefore, the resonance curves were considerably different, with amplitude variations as high as 100%, again particularly at the upper end of the speed range, where in this instance the curves with pump discharge are lower than those for zero load for most harmonics.

The various disturbances mentioned above can become particularly troublesome if the "disturbance curve" Δy as a function of cam angle φ contains a number of large-amplitude low-order harmonics which may excite spring surge.

Surge-Free Cam Drives

The basic design problem is to obtain acceptable stresses in the spring material while avoiding excessive reductions of the upper speed limit at which the cam system can operate satisfactorily. The possible solutions are as follows:—(1) The spring is allowed to operate only in a narrow speed range between two resonance peaks; this can be achieved with constant-speed engines driving generators, etc. (2) Spring surge is eliminated as far as possible over a wide range of speeds, either by additional damping or by suppression of certain harmonics from the cam contour.

Cam mechanisms have very little inherent damping and from large numbers of tests it can be said that even a cam-lift harmonic $\sqrt{a_n^2 + b_n^2}$ of 0·02 mm can cause considerable surge amplitudes. If Y_n denotes the maximum total swing of the middle coil of the spring, it can be expected that the dynamic magnification, i.e., the ratio $M = Y_n/[2\sqrt{a_n^2 + b_n^2}]$, is of the order of 50 to 100.

Frictional damping is very effective and is obtainable by providing a friction surface at the antinode, i.e., at the middle coil of the spring. The frictional member, however, requires extra space, is difficult to set up correctly, and is generally an expensive solution. Moreover, it also tends to favour fretting corrosion of the spring surfaces. Another method of absorbing vibratory energy is to provide additional flexibility at the spring supports, but this also has its difficulties, and moreover it has been found that such arrangements are more effective at low speeds, where high-order harmonics occur, than towards the upper speed limit where the excitation is greater and damping is most needed.

There is also "dynamic damping" or detuning, which is obtainable by means of a non-linear spring with a variable rate, i.e., a spring in which the number of active coils varies during each cam-lift cycle. The spring vibration is then constantly "out of step" with the harmonics of the cam excitation. The method is simple and inexpensive, it reduces surge in many cases, and is frequently employed. However, careful examination shows that its effective advantages are somewhat problematical, as evidenced by the resonance curves in Figs. 4a and 4b, in which the region where cam lift occurs is between the two vertical dotted lines. It can clearly be seen that the cam-angle distance φ_y between two successive peaks in the cam-lift region is smaller than the distance φ_0 between two peaks in the zero-lift (base-circle) region, so that there is a detuning effect during the cycle.

It is now necessary to consider what effect this detuning has on stress conditions. Compared with a constant-pitch spring, the variable-rate spring has a certain number of coils which close up and become "coil-bound" during the cam-lift cycle. If both springs surge with the same maximum amplitude, there is more stress in the variable-rate spring, because it has a reduced number of active coils taking part in the vibration (although the total number of coils is the same for both springs in this comparison). Consequently, an improvement in the form of a reduction in stress is obtained with the non-linear spring only if the amplitude of vibration is reduced below a certain value as compared with the conventional constant-pitch spring. The amplitude reduction below which a reduction in stress also occurs is a function of the stiffness/displacement curve of the non-linear spring.

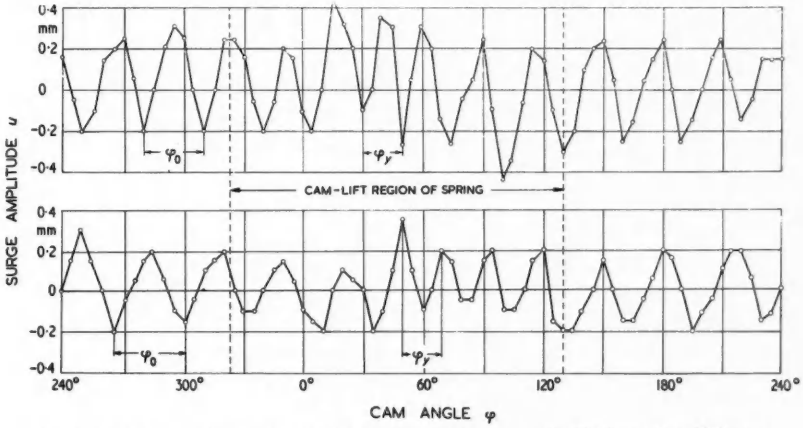

Fig. 4. Surge of a non-linear spring, (a) 13th harmonic at 1790 rpm, and (b) 12th harmonic at 1950 rpm.

The second possibility, i.e., the elimination of harmonics on the cam contour, will now be considered. The corrections to the original cam-lift curve must be suitable for use in normal cam manufacture and such that the modified motion of the cam mechanism still fully complies with the type of conditions required. Such corrections can now be achieved in practice.

The "spectrum" of the cam contour, i.e., the amplitudes of its harmonics plotted against their order numbers, may show "jumps" or discontinuities instead of gradually decreasing values. In such cases, it is possible to employ a method suggested by Hussmann,[3] which enables several successive harmonics occurring in the speed range to be eliminated. Hussmann has also indicated another method for reducing to some extent all the harmonics in the speed range. Both methods, however, leave residual harmonics of finite amplitude in the range of operating speeds. In addition to the "theoretical spectrum" of the ideal cam curve, there is a "manufacturing spectrum" due to manufacturing errors. It will therefore be an advantage if the theoretical spectrum is made equal to zero for all the harmonics in the speed range considered.

In the following, some simple methods will be described which give zero-amplitude harmonics throughout the running range. They differ from Hussmann's procedures in that the modifications are applied to the entire cam contour. The correction functions successively obtained do not alter the type of cam action required, and their effect is confined to that portion of the lift curve where small alterations of the cam contour are fully permissible.

(To be concluded)

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U.S.A.

The Effects of Oil Viscosity on Piston-Ring Wear

By M. POPOVICH and L. E. JOHNSON. (From *Automotive Industries*, Vol. 114, No. 1, January 1, 1956, pp. 57-58, 106, 3 illustrations.)

PROPER lubrication of the modern high-speed internal combustion engine is one of the great problems facing the engine designer, the oil companies producing lubricants, and the owner who must operate and see to the servicing of the engine. The wear of rings and cylinder walls increases engine clearances to the point where oil consumption becomes excessive and engine performance suffers. To prolong the economic service life of the engine, lubricants which reduce or eliminate the various types of wear must be utilized.

A property of lubricating oil generally considered of prime importance is viscosity. The oil must be fluid enough at low temperatures to provide proper lubrication when starting, yet not fail at the higher temperatures which exist after warm-up. To provide this type of lubrication, multigrade oils, which employ viscosity-index improvers, have recently been developed by several oil companies. The lubricants also must provide an oil film of sufficient viscosity to support the load imposed upon it and to prevent metal-to-metal contact of moving surfaces. The oil film also must protect the metal surfaces from the corrosive products of combustion.

Little quantitative information has been published which correlates engine wear with oil viscosity, and it was decided, therefore, to make tests on an engine under controlled conditions, using oils of various viscosities. The radioactive-tracer method was selected as the method of wear measurement because of its convenience and accuracy. More recent techniques and instrumentation were incorporated in the radioactive-tracer method which was adopted at Oregon State College in 1952 as a tool for engine research. The two compression rings from the one-cylinder Lauson H-2 oil-test engine used in the test were irradiated and the engine was operated with oils of the same base having viscosities ranging from SAE 5 to SAE 50, including multigrade SAE 10-30. Engine load was selected as two-thirds of maximum for the engine. A jacket temperature of 212°F was sufficiently high to eliminate corrosive wear; the possibility of abrasive wear was minimized by frequent oil change. It was expected that the results would show wear from friction alone, unless the fairly severe operating conditions should allow scuffing.

The high wear rate found in the case of the SAE 5 oil indicates that its lower volalitity causes it to evaporate from the cylinder walls and to allow intermittent metal-to-metal contact. Also, it may be possible that the oil film is so thin that it fails under load and provides only the barest boundary lubrication. A mild scuffing even may be indicated. As the oil viscosity is increased it would be expected that thick-film lubrication would exist, and increasing the viscosity would only increase the film thickness and reduce the wear rate. However, as the oil becomes more viscous after passing optimum viscosity, the wear rate increases. A reasonable explanation is that, as the oil becomes more viscous, the flow of oil to the lubricated surfaces is reduced and adequate lubrication does not exist.

It was also found that the SAE 10-30 oil is not better than regular oils in reducing wear under conditions of the test. Actually, wear experienced with the multigrade oil was greater than with the SAE 20 and less than with the SAE 30, though it should be noted that the conditions of this particular test should not be expected to give results as favourable to the multigrade oils as might other selected conditions.

The test definitely indicates that there is an optimum viscosity for wear reduction. It appears that the range of SAE 10 to 20 oils is ideal for the Lauson engine. This quantitative result from the Lauson engine can, however, be applied with reasonable accuracy to other engines, because the conditions affecting the lubrication of the piston rings are comparable. The conclusion may also be drawn that the common practice of using lubricating oils of higher viscosity, when oil consumption begins to increase, probably hastens piston-ring and cylinder wear.

Carbide Phase Changes on Tempering a Molybdenum Steel

By K. Kuo. (From *Jernkontorets Annaler*, Vol. 140, No. 1, 1956, pp. 24–46, 23 illustrations.)

THE tempering of quenched carbon steels can be roughly divided into three stages,[1] i.e., (1) precipitation of ε-iron carbide and a low-carbon martensite (below 150°C), (2) decomposition of retained austenite into bainite (150 to 280°C), and (3) precipitation of cementite (above 300°C). On tempering certain alloy steels an alloy carbide may be formed, depending upon the kind and amount of the alloying element present. Since the nucleation and growth of an alloy carbide require the diffusion of the alloying element, which is a relatively slow process at temperatures below 500°C, the fourth stage of tempering, i.e., the conversion of cementite into an alloy carbide, generally does not take place below this temperature.

The present paper is an account of the microstructural changes accompanying the carbide conversion $Fe_3C \rightarrow Mo_2C$, as revealed under optical and electron microscopes. Since the main interest lies in the precipitation of Mo_2C, this has been studied both *in situ* and in the extracted state. In addition to microscopic examination, hardness measurements on the tempered steel specimens and X-ray analysis of the extracted carbides were also made, to gain more insight into the structural changes accompanying the tempering process.

The steel used in this investigation contained 0·11% C, 0·08% Si, 0·12% Mn, and 2·14% Mo, the reasons for choosing a steel of this particular composition being, among others, as follows:—

(1) The steel has a Mo:C ratio of 2·43, so that the conversion of Fe_3C into Mo_2C can occur rapidly and completely.
(2) A low carbon content should yield a small amount of carbide and an open structure, greatly facilitating study of the microstructure.
(3) After quenching, the steel should virtually contain martensite only and no retained austenite, and therefore any secondary hardening phenomenon, if it occurs, can be attributed to the precipitation of the Mo_2C carbide.

The austenitizing treatment lasted 30 min at 1150°C, and no undissolved carbide particles were found in steel specimens first quenched in brine and then in liquid air. The amount of retained austenite has not been determined, but was assumed to be nil, since an earlier X-ray examination[2] made on a steel with 0·18% C and 3·88% Mo established the absence of retained austenite. The tempering time, unless otherwise specified, was 1 hr.

Hardness Measurements and X-Ray Analysis

Insofar as change in hardness with increasing tempering temperature is concerned, tempering up to 200°C causes no change in the hardness of this steel, as is only to be expected from its low carbon content. At 250°C hardness starts to fall, though only slightly, and continues to fall up to 450°C, perhaps because of the precipitation and growth of cementite. Above 500°C hardness starts to rise and reaches a maximum at 600°C, followed by a very rapid decrease.

The secondary hardening phenomenon in this steel cannot be due to the transformation of retained austenite, as is sometimes the case with high-carbon alloy steels, but might be accounted for by the precipitation of an alloy carbide at between 500 and 600°C.

The X-ray diffraction work on anodically extracted carbides proves that cementite exists at and below 600°C, and that the Mo_2C carbide begins to appear at 650°C. The Mo_2C diffraction patterns are extremely diffuse, indicating a very small particle size. This clearly shows that the carbide existing below the hardness peak is cementite, and above the hardness peak Mo_2C, confirming the findings of an earlier investigation by the author on a steel with 0·18% C and 3·88% Mo.

The X-ray diffraction pattern of Mo_2C formed below 650°C showed abnormal relative intensities with (100) much stronger than (002), analogous with the abnormal relative intensities of the ε-iron carbide previously reported by Jack.[3] According to Jack, this anomaly can be satisfactorily accounted for by the needle-like shape of the ε-iron carbide, with (101) planes perpendicular to the needle axis.

It is well known that the X-ray powder method is not sensitive in dealing with a phase of very small particle size (<1000Å), especially when the phase does not exist alone and its percentage in the mixture is low. Therefore, X-ray findings can only be used to prove the presence of a phase, but not its absence. In order to overcome the drawback of this insensitivity, and to reconcile the discrepancy between the temperature at which the Mo_2C carbide is found by X-ray diffraction (650°C) and the temperature at which this carbide is expected to appear (500°C), it was thought that microstructural studies might yield some new information.

Optical Micrographs

The tempered specimens were etched in 1% nital for about 20 to 30 sec and examined under an optical microscope at ×400 and ×1800. The lower magnification afforded very little information concerning the precipitation of cementite and Mo_2C, but the higher magnification proved satisfactory for the purpose. Thus, the precipitation of cementite is obvious at 350°C (Fig. 1), though it had already commenced at a lower tempering temperature (250°C). After tempering at 500°C the structure did not appear to differ noticeably from that in Fig. 1, exhibiting the typical acicular appearance of tempered martensite.

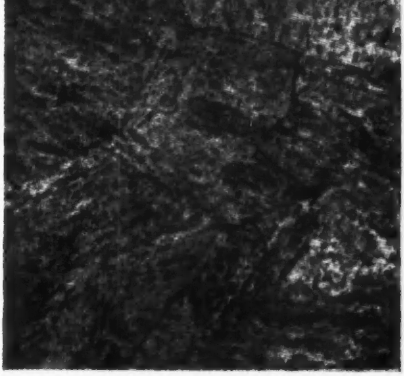

Fig. 1. Optical micrograph of Fe_3C in steel tempered at 350°C for 1 hr. (× 1800)

A decrease in the amount of carbide seems to take place between 550 and 600°C. Large carbide particles are usually situated at the interface of martensite (now ferrite) plates, within which very few carbide particles can be found. The above-mentioned decrease becomes more pronounced at 650°C, hardly any carbide particles being discernible at the ferrite interfaces. Moreover, there are very few carbide particles at the boundaries of austenite grain, where carbide particles are most likely to be present. Meanwhile, the ferrite plates begin to show the effect of different orientations.

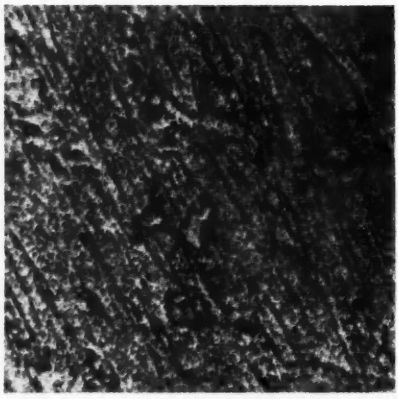

Fig. 2. Optical micrograph of Mo_2C in steel tempered at 750°C for 1 hr. (× 1800)

The orientation effect becomes more evident at 700°C; the difference in etching between ferrite plates disappears and each austenite grain consists of large, differently oriented blocks of ferrite. Furthermore, a reprecipitation of carbide seems to take place, though the particles are extremely small and can barely be discerned. At 750°C (Fig. 2) these newly precipitated carbide particles become large enough for their alignment to be clearly seen. This micrograph was taken from a single block of ferrite with a seemingly, though not really, uniform orientation. The carbide lines seem to locate the old interfaces of ferrite plates.

From these optical micrographs it might be concluded that the conversion of Fe_3C into Mo_2C occurs between 600 and 700°C.

Electron Micrographs

Conventional Replica Method:—

In the conventional replica method used in the present investigation, the steel specimens were etched in 1% nital for about 20 to 30 sec, dried, dipped in a solution of 0·7% Formvar in dry-distilled chloroform, and then held obliquely above this solution, polished surface upward, until dry. These precautions were taken in order to avoid any condensation of moisture on the steel specimen which would lead to small round cavities in the replica. This thin replica with a bluish-brown tint was then covered with a protective film by applying a 3% solution of collodion in isoamyl acetate. By soaking the steel specimen alternately in hot and cold water this double film could be stripped from the specimen. In order to get rid of any carbide particles removed together with the replica from the steel specimen, this double film was washed first for 5 hr in 10% H_2SO_4 and then in water. After dissolving the protective film in isoamyl acetate, the replica was dried on a copper or nickel grid, and was then ready for electron-microscope examination.

The light particles observed at 300°C and at 500°C (Fig. 3) are cementite, and are larger at the interfaces of the ferrite plates than inside them. Contrary to experience gained in tempering carbon steels, increasing the tempering temperature from 350 to 500°C causes practically no structural changes in this molybdenum steel. In other words, no significant carbide growth and coagulation of the kind common in carbon steels seem to have taken place. At 350°C the carbide particle size is similar to, and at 500°C smaller than, that found in a low-carbon steel tempered at the same temperatures. This may perhaps explain why molybdenum more effectively retards softening at high tempering temperatures (500 to 650°C) than at temperatures below 300°C.[4] In Fig. 3 it will be seen that some of the carbide particles appear to display a platelet habit and a regular orientation—not uncommon occurrences in carbon steels tempered at low temperatures. The same tendencies were observed in similar electron micrographs of steels tempered at 550 and 600°C. At 550°C small amounts of large elongated carbide particles were observed, lying at the interfaces of ferrite plates, within which numerous minute acicular carbide particles could be found. Tempering at 600°C yields a similar structure. There seems to be little doubt that the large interface carbide particles are cementite, but the identity of the small carbide particles is difficult to ascertain.

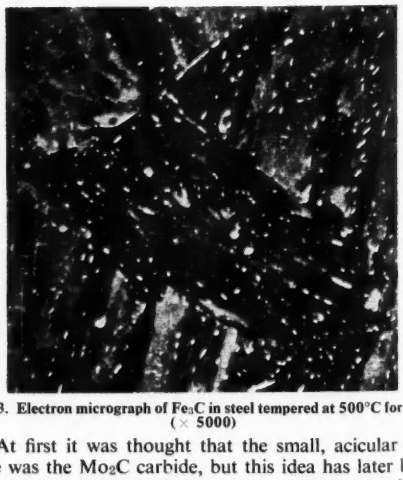

Fig. 3. Electron micrograph of Fe_3C in steel tempered at 500°C for 1 hr. (× 5000)

At first it was thought that the small, acicular carbide was the Mo_2C carbide, but this idea has later been discarded on the ground that the particles are too large to be Mo_2C carbide. After enlarging these micrographs, these needle-like carbide particles are found to be about 1000 Å in length and 300 Å in diameter. At 600°C the extracted Mo_2C particles are only about 200 Å in length and 30 Å in diameter. They are far too small to be resolved by the conventional replica methods. Admittedly, carbide particles always appear somewhat larger in a replica than in the free state (the enlarging effect of etching has already been pointed out by Habraken,[5] (among others), but this enlargement can hardly amount to between 5 and 10 times. Presumably, the particles are small cementite particles.

The orientation of ferrite seems to suffer no change within the temperature range between 350 and 600°C. Islands of ferrite with a different orientation from the

surroundings appear either in a lighter or a darker tone; in optical micrographs they would appear as black dots and be mistaken for cementite particles. Precautions should therefore be taken in identifying small particles in an optical micrograph, when an attacking but non-colouring etchant is used.

The orientation of ferrite changes drastically at 650°C, and the ferrite islands previously noted can no longer be seen (Fig. 4). However, thanks to the deep etching effect at the boundaries, the ferrite plates can still be differentiated. The mottled appearance of Fig. 4 gives the first signs of the precipitation of Mo_2C, which is well established from the X-ray analysis. The poor contrast and blurred boundary of these carbide particles, apart from a few at the austenite grain boundary, is probably due to their extremely small size. Cementite seems to have disappeared completely at this temperature. Incidentally, the small bright circles are not carbide particles, but cavities in the replica produced by condensation of water during its preparation—a possibility which has already been mentioned.

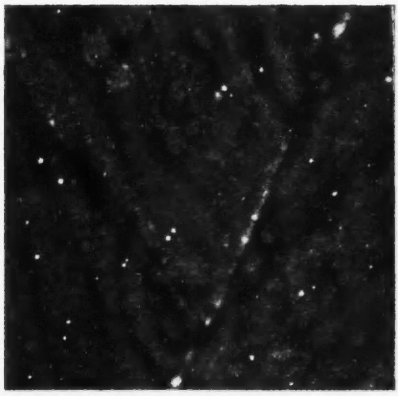

Fig. 4. Electron micrograph of steel tempered at 650°C for 1 hr, showing first signs of precipitation of Mo_2C. (× 12,000)

In spite of repeated trials it has not been possible to produce from specimens tempered at this temperature a replica containing the small, well-defined, acicular carbide particles found at 550 and 600°C. This supports the suggestion that they are not Mo_2C carbide particles. At 700°C the Mo_2C carbide particles grow to a better-defined size, and are probably aligned along the interfaces of ferrite plates.

In brief, this series of electron micrographs provides more detailed information on the size, shape, and distribution of cementite and Mo_2C, and on the orientation of ferrite, than does the series of optical micrographs. However, evidence of the precipitation of Mo_2C at temperatures below 650°C is still lacking.

Extraction Replica Method :—

The replica, unless treated with sulphuric acid, often contains some carbide particles dislodged from the steel specimen. During the study of this steel tempered at 700°C and above, such carbide contamination was found to be extremely pronounced, possibly because of the smallness and the special shape of Mo_2C. However, this is considered an advantage rather than a drawback, because the carbide particles can be extracted from the steel and still be studied as if they were *in situ*. This replica method, owing to its higher resolution, is especially suitable for the study of small particles. Fisher[6]

Fig. 5. Electron micrograph (extraction replica) of steel tempered at 700° C for 1 hr, showing the distribution of Mo_2C needles. (× 12,000)

first used the term " extraction replica ", though he has employed a second etching through the replica to achieve this end.

Fig. 5 shows the structure from tempering at 700°C. Except for the relatively large carbide particles—presumably also Mo_2C—at the austenite grain boundaries and those in the ferrite grains which are only slightly etched, nearly all the carbides are extracted from the steel specimen and are present in the replica. The Mo_2C needles lying parallel to the steel surface are intact, but those at large angles to the surface are broken during the removal of the replica and appear as dots. The carbide needles exhibit no regular orientation, though sometimes they do lie in parallel planes, appearing as dots in parallel lines if the planes are sectioned obliquely by the polished surfaces, or as needles in ferrite plates if the planes are parallel to the surface.

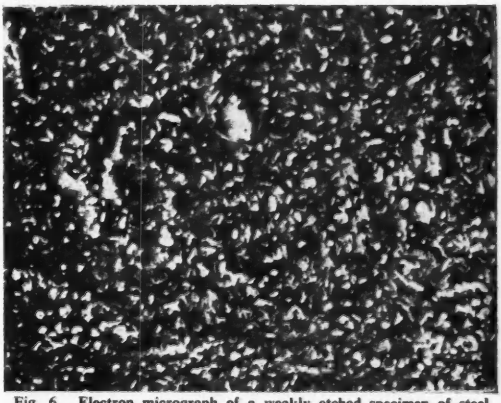

Fig. 6. Electron micrograph of a weakly etched specimen of steel tempered at 750°C for 1 hr, showing extracted (dark) and unextracted (light) Mo_2C needles. (× 12,000)

The Mo_2C needles grow only slightly when the tempering temperature is further raised to 750°C. Fig. 6 shows the structure of a weakly etched specimen. Only a small amount of the Mo_2C carbide is extracted, and the remainder appears as light needles and dots, the counterparts of the black needles and dots. The micrograph serves to prove that the latter are really extracted carbide particles, and not due to any foreign contamination during the preparation of the replica. The light needles appear in poor contrast in the electron micrographs,

implying that they are really thin needles instead of plates.

The sequence in which the carbides found in tempering medium molybdenum steels appear is Fe_3C, Mo_2C, and M_aC_b, but it usually needs several hundred hours tempering at 700°C for M_aC_b to appear. The M_aC_b carbide has not been found either in the present steel or in chromium-molybdenum steel with a nominal composition similar to that used by Habraken after tempering at 700°C for 250 hr.

Using his special extraction replica method, Fisher[6] has also obtained an electron micrograph taken from a steel with 3·2% Mo (the carbon content and heat treatment are not reported), showing straw-like and needle-like carbides, similar to those presented here, with diameters as small as 100 to 200 Å.

Attempts have been made to use the present extraction replica method to study carbides at 600 and 650°C, but these have not been successful. When the carbide particles are very small, it is not impossible that, once free from the surrounding ferrite, they fall from the surface either during the etching or subsequent washing.

Extracted Carbide :—

Carbides were extracted from steel specimens by dissolving the ferrite either chemically or electrolytically ; the former implies a 10-sec dipping in HNO_3 (1:1),[7] and the latter a 30-sec electrolysis in HCl (1:20), the current density being 0·1 A/cm². These two methods gave similar results. After washing in water, alcohol, and isoamyl acetate, the carbide particles were freed from the steel specimens by supersonic vibrations, and a suspension in isoamyl acetate was thus obtained. A drop of this suspension was allowed to dry on a thin Formvar film supported by a copper grid, and was examined in the electron microscope.

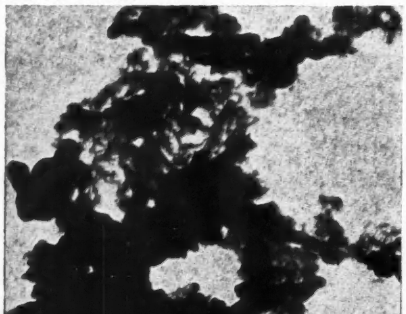

Fig. 7. Electron micrograph of steel tempered at 550°C for 1 hr, showing Fe_3C and Mo_2C "threads". (× 75,000)

At 450°C the cementite particles formed usually cluster together during extraction, but their dimensions as estimated from the separate particles, are of the order of 300 to 1000 Å. At 500°C, besides the large cementite particles of the same size as those at 450°C, clusters of tiny carbide " threads " are observed. The latter increase in number, but not in size, as the tempering temperature increases (Fig. 7), and become the predominant constituent at 600°C. The dimensions of these tiny carbide particles are about 200 Å in length and 30 Å in diameter. The particle size of cementite seems to be slightly diminished.

Tempering at 650°C produces Mo_2C carbide crystals, of various sizes, the length varying from 200 to 700 Å and the diameter from 30 to 100 Å, implying that carbide growth has taken place. Since the tiny Mo_2C " threads " found at 500 to 600°C are still present at this temperature, the precipitation process is perhaps not yet finished at 650°C. Cementite seems entirely absent.

Fig. 8. Electron micrograph of steel tempered at 700°C for 1 hr, showing Mo_2C needles. (× 75,000)

Increasing the tempering temperature from 650 to 700°C causes a noticeable growth of Mo_2C to well-developed needles about 1000 Å in length and 150 Å in diameter (Fig. 8). They are of about the same dimensions as those observed earlier in the extraction replica (Fig. 5). Note that the needles have a nearly uniform size, which increases only slightly when the temperature is further raised. It should be mentioned, however, that round Mo_2C carbide particles are also present in steel specimens tempered at and above 650°C.

This series of electron micrographs has proved that the precipitation of acicular Mo_2C begins at 500°C, continues to 550°C, attains its maximum rate at 600°C, and finally ceases at 650°C, and that the growth of Mo_2C is only obvious above 600°C, appearing to be most rapid between 650 and 700°C. The acicular shape of Mo_2C observed in the electron micrographs readily explains why the X-ray powder photographs of Mo_2C formed below 650°C always show abnormal relative intensities.

Although the acicular appearance of extracted Mo_2C carbide has previously been reported by several investigators, this is the first time that it has been observed in steel specimens tempered for short periods below 600°C.

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Flame Plating with Tungsten Carbide

By R. H. ESHELMAN. (From *The Tool Engineer*, Vol. 36, No. 1, January 1956, pp. 117–122, 9 illustrations.)

Developed by Linde Air Products Co., U.S.A., and first reported in 1952,* *a commercially practicable process, based on accumulated experience, has been evolved for depositing carbide coatings by blasting tungsten carbide particles through a special gun, using explosive gases as a carrier. This method of bonding, known as flame plating, retains the properties of both the base material and the coating.*

CARBIDE materials offer such unusual advantages for a wide variety of wear applications that it was inevitable that some means of utilizing this coating or "plating" material for metal surfaces would be developed. Although solid carbide inserts are highly successful for many applications, they have distinct disadvantages. Briefly, these involve high cost, size limitations, and design requirements. Plating affords an extension of the field for carbides because it largely overcomes these objections.

In the Linde detonation-gun combustion process of carbide plating, the plating applied is composed of tungsten, carbon, and 8% cobalt. The coatings differ from cemented carbide or sintered carbide structures in that they consist essentially of a complex series of phases, derived from the W-C-Co system (Fig. 1), rather than a simple two-phase W-C-Co type of structure.

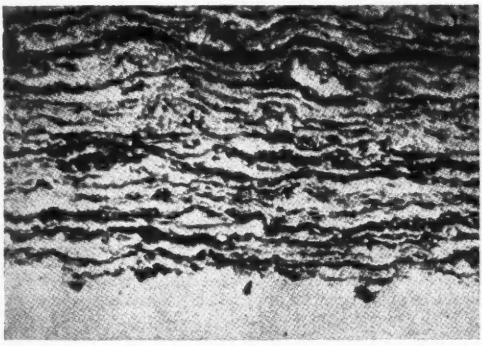

Fig. 1. **Photomicrograph of carbide coating produced by the Linde process.**

By nature of the process, the coating consists of layers, or laminae, which are clearly revealed by etching. Each layer is composed of bodies which are flattened, spherical, or angular, large or minute, related to each other in a more or less periodic manner. Even though there is a distinct boundary between the coating and the base metal, there is no visible oxide layer. The exact type of bond between coating and base metal has yet to be determined; however, according to indications it is more than mechanical.

The density of the coating is substantially identical with that of solid cast material. Porosity is less than 1%. Adherence of the coating is excellent, as demonstrated by the fact that it may be ground to the interface without peeling. The coating has a smooth matte surface which may be brought to a high polish by the precision grinding and polishing procedures used on carbide materials.

DESCRIPTION OF THE PROCESS

The detonation gun used in the process employs a barrel and a mechanism for loading precise quantities of tungsten carbide powder, acetylene, and oxygen into the firing chamber, as illustrated schematically in Fig. 2. The tungsten carbide powder remains suspended in the explosive gases until a spark ignites the mixture, producing heat and pressure waves. The waves are concentrated by the shape of the barrel within a small area, producing tremendous heat and pressure.

As the temperature reaches 6000°F detonation occurs, with the flame front moving at supersonic velocities. The tungsten carbide powder is suspended in the burned gases, and the pressure inside the barrel reaches 10,000 psi in 0·003 sec. After detonation, the shock wave dissipates into the air. The gases in the barrel burst out, carrying the tungsten carbide powder. The particles of tungsten carbide become partially molten and are deposited on the workpiece at a velocity of approximately 9000 fps, the speed of the detonation wave.

Though the frequency of detonation may be varied, it is usually several detonations per second for most carbide applications. The succession of blasts striking the surface of the part builds up the particles, fusing them together until the desired thickness is obtained. Nitrogen is introduced into the gun from a conduit and a poppet valve between each charge, to purge the mixing chamber and to protect the valves, preventing flash-back on detonation. An additional purpose of the nitrogen is to drive out the hot combustion products and to form a protective wall between them and the next combustible mixture charged.

The size and length of the gun barrel are not critical, provided that the length is at least several times the diameter of the bore. If the barrel is too short, the mixture will not detonate. Thus, the size of the gun barrel will vary to suit the particular application.

Simple air cooling is ordinarily adequate for the barrel. Although the temperature of the wave is high, upwards of 6000°F, much of the heat is dissipated before the particles strike the workpiece. Thus, inherently, little heating of the workpiece results. The temperature of the workpiece seldom exceeds 400°F. Heat distortion, therefore, is virtually no problem. Such heating as does occur can be readily overcome, or compensated by the use of a cooling blast, such as air or CO_2. Internal water cooling can be used when the workpiece is hollow. Precision and semi-precision parts can be plated without danger of changes in metallurgical properties or physical distortion.

A clean surface is required for the process, preferably roughened as by grit-blasting, or thinly coated with a soft metal such as copper, nickel, or cobalt. The part to be plated is positioned about 3 in. from the open end of the gun. Under typical conditions, a layer of tungsten carbide, 0·020 in. thick, can be deposited at a rate of about 1 sq in./min.

Most metals can be plated, including steels, cast iron, aluminium, copper, brass, bronze, molybdenum, titanium, nickel, and magnesium. Chromium plate and sintered carbide, however, cannot be coated. Plated parts may be recoated if the original coating is first removed. Stripping is readily accomplished by means of an electrolytic bath.

* See *The Engineers' Digest*, November 1952, p. 369. Ed. E.D.

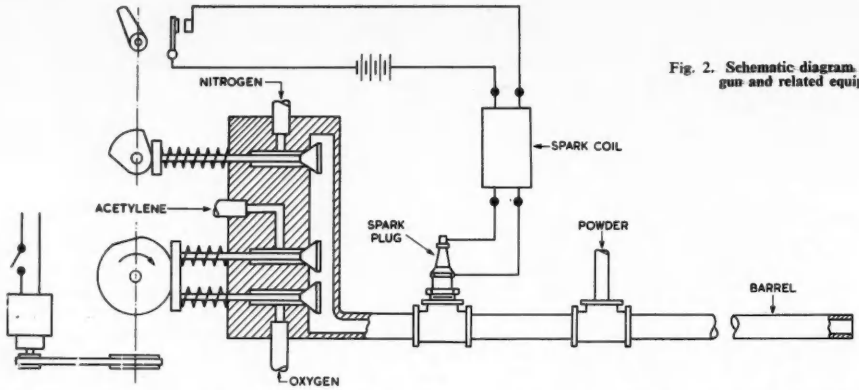

Fig. 2. Schematic diagram of detonation gun and related equipment.

Coatings are commonly deposited in thicknesses of 0·002 to 0·010 in., depending upon subsequent finishing. The larger amounts are deposited where part of the coating is to be subsequently removed in finishing. The surface of plated parts is about the consistency of fine emery paper, i.e., 125 micro-inches r.m.s. Plated products may be used in this condition or finished to various degrees of smoothness by brushing, grinding, and lapping methods, depending on the application. Finishes of less than 1 microinch r.m.s. can be secured, where desired.

The size of parts that can be plated is limited primarily by the handling equipment available. Round parts are usually held in conventional chucking arrangements, while long, flat surfaces are traversed by a fixture. On flat areas to be finish-ground, the limits of plating at present are $\frac{3}{4}$ in. in width and 62 in. in length. Where indications of overlap between coating passes are not objectionable, limitations can be extended to 9 in. in width. Internal diameters, $\frac{3}{8}$ in. or larger, can be coated where the depth of the hole does not exceed the diameter. Blind holes or cavities cannot be successfully coated. Grooves and similar depressions can often be coated but some difficulty may be experienced.

The shape of the part must be considered in making the decision to plate by this process. Since the coating is formed by particles striking the surface at high speeds, only areas which allow particles free and sufficient access can be plated evenly. Narrow holes, blind cavities, and deep, V-shaped grooves are thereby eliminated. Plating of corners is sometimes unsatisfactory because of development of weak spots. Also, the process is not suitable for metal-cutting tools, because the coating does not withstand this type of use. In addition, since the coating is thin, insufficient material is provided for resharpening.

While the coating is not designed to protect parts from corrosion, it has been found suitable for high-temperature parts where fretting corrosion might be present. Reagents which attack cobalt will attack the tungsten carbide coating. These include most acids and some alkalis. Mild alkalis, detergents, lubricating oils, and atmosphere free from acid fumes in most cases have no detrimental effect.

Physical Properties of the Coating

Tungsten carbide plating has excellent resistance to thermal shock. Strips loaded in tension to 15,000 psi, heated to 1350°F in 45 sec, and cooled to 120°F in 30 sec showed good test results. A plating of 0·010 in. failed after 6 cycles of heating and cooling ; 0·005-in. plate started to fail after 200 cycles and 0·002-in. plate was unaffected after 500 cycles.

Hardness of the tungsten carbide coating averages about 1350 Vickers Pyramid. Particles of the coating are harder than indicated. The difference between actual particle hardness and measured hardness is due to the cobalt matrix.

The modulus of elasticity of the coating is quite low, approximately 27 million psi compared with 64 to 92 million psi for sintered tungsten carbide. However, for maximum mechanical shock resistance, the coating should not exceed 0·003 in., whether used in the as-coated or ground-finish condition. Stress causing permanent distortion of the base metal may impair coatings, regardless of thickness. The plating has a negligible amount of internal structural porosity, less than 0·5%, and the coefficient of friction is comparatively low.

Production Requirements

As most carbide-plated parts are of a precision nature, care must be taken, especially in finishing operations. For non-critical applications, the as-coated surface has an excellent degree of roughness, providing gripping power for such parts as dogs and collets.

Non-precision parts requiring a fairly smooth surface can be given an intermediate finish of approximately 20 to 100 microinches r.m.s. These can be secured by lapping, flexible-belt grinding, or brush finishing. Where close tolerances are required, however, the coating must be ground and lapped.

Parts to be plated should be undersized, to allow for the finished thickness of the coating. Sharp corners should be avoided on any portion of the part receiving the coating. A minimum of 0·015-in. radius for chamfer is recommended when possible, not only where the finished part may be subjected to abuse but also to avoid chipping during grinding operations.

Ordinarily, 0·003 to 0·004 in. of coating is removed in finish-grinding and lapping to close dimensional tolerances and low microinch finishes. For grinding operations, a 100-concentration resin-oilbonded diamond wheel, with the usual wheel speed of 6000 to 6500 sfpm, should be used. Silicon carbide wheels are not recommended. The wheel can be dressed with an abrasive stick when it becomes dull, as indicated by hard grinding or chattering. Flood-type coolant must be used. Dry grinding will result in a damaged coating. The best coolant is water, with a small amount, 1 to 2%, of a rust inhibitor such as a soluble grinding oil.

The "Sweeping-Beam" Method of X-Ray Analysis

By F. REGLER. (From *Radex Rundschau*, No. 8, December 1955, pp. 664-683, 37 illustrations.)

THERE are various methods of examining the structure of a material by means of X-rays. Of these, the direct or penetration method of recording on flat films is shown in Fig. 1, in which the primary beam emitted from the anode *A* of the X-ray tube passes through the aperture of the diaphragm *D* and impinges on the sample *S*. The beam is diffracted by the lattice elements of the sample and emerges as a family of coaxial cones of interference lines, which form discrete patterns on the flat film *F*, mounted normal to the direction of the primary beam.

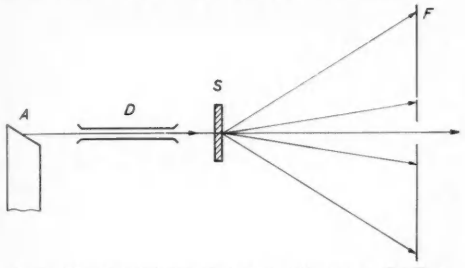

Fig. 1. **Direct method of producing crystallograms on flat films.**

The arrangement for recording on flat films by the back-reflection or reflex method is shown in Fig. 2, in which the primary beam from *A* passing through the aperture of the diaphragm *D* is reflected from the sample *S* onto the flat film *F*.

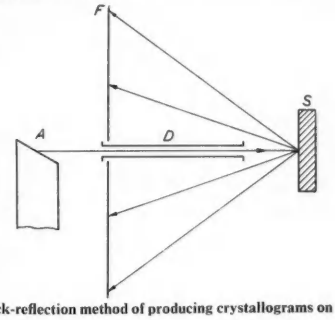

Fig. 2. **Back-reflection method of producing crystallograms on flat films.**

For polycrystalline samples, the classical method is that of Debye-Scherrer (Fig. 3). The sample *S* is surrounded by a cylindrically arranged film *F*, on which the diffracted beams form interference cones producing algebraic curves of the 4th order, called Debye-Scherrer lines. In flat-film crystallograms these lines are circles.

In many investigations, it is sufficient to determine the aperture angle 4θ of the interference cones. By means of Bragg's equation

$$n\lambda = 2d \sin\theta$$

where λ = wavelength of the monochromatic X-ray radiation, θ = angle of incidence, and n = a small whole number, it is possible to evaluate the lattice constant d, i.e., the distance between the planes of atoms in the sample. For the study of the fine structure of crystals, however, the positions of the atoms in the lattice must also be determined, and this is achieved by taking into account the intensity ratios of diffracted X-ray radiations obtained with various angles of incidence.

Further indications can be obtained with the "cone" methods developed by the author. As shown in Figs. 4 and 5, whether direct or back-reflection methods are employed, additional interference lines can be recorded if the film *F* is located at an angle to the axis of the primary beam, instead of perpendicular to it. With a cone camera having an aperture angle of 60 deg., the film forms an equilateral cone, and the interference lines recorded form semicircles.

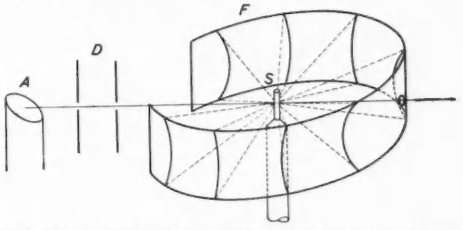

Fig. 3. **Classical Debye-Scherrer method of producing crystallograms on cylindrically arranged films.**

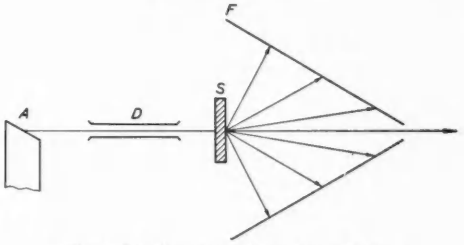

Fig. 4. **Direct cone method, according to Regler.**

The interference lines have a line width which is also a function of the geometric dimensions of the aperture. If the diffracting area of the lattice plane is greater than the projection of the primary beam impinging on it, the entire primary beam will be diffracted. If the lattice area is much smaller, then it will intercept only a portion of the beam, and this portion only will produce an image. For fine-grain samples, therefore, the interference cones are actually closely packed layers of coaxial cones in which the X rays are on average homogeneously distributed. With samples of larger grain size, the number of crystals receiving the primary radiation is smaller ; hence, the number of diffracted interferences is reduced considerably, while their cross-section increases. The cone surfaces are then no longer homogeneously filled but contain individual beams only, giving interference spots which can be connected together to obtain Debye-Scherrer lines. Alter-

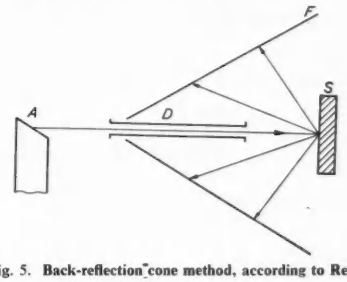

Fig. 5. **Back-reflection cone method, according to Regler.**

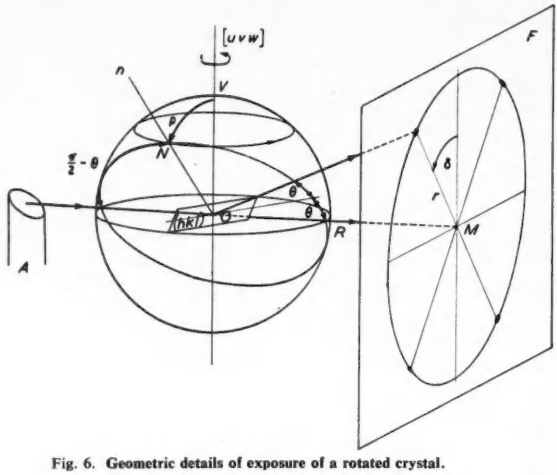

Fig. 6. Geometric details of exposure of a rotated crystal.

natively, during the recording, the rod-shaped sample can be rotated in order to increase the number of diffracting angles and hence the number of interference spots to such an extent that the images appear as homogeneous dark lines. If this still is not sufficient the sample can be moved axially up and down during its rotation to increase the homogeneity of the lines recorded.

It has been shown by the author* that, in many cases, the relative rotation of the sample is not sufficient to obtain crystallograms suitable for subsequent evaluations, if the number of crystals involved in the diffraction is too small. To increase their number, it is then necessary to displace the sample parallel to its axis, with simultaneous rotation of the film to prevent the formation of blackened areas due only to the movement of the sample. This " parallel scanning " is very effective in such cases.

In general, the primary X-ray beam contains not only monochromatic radiation but also bremsstrahlung, which is polychromatic, in that it covers a continuous range of wavelengths. From Bragg's equation it can be seen that this continuous radiation spectrum can be diffracted at practically every angle of incidence θ, even with discrete, i.e., clearly separated, values of interplanar distances *d* for fine-grain samples with irregularly distributed small crystals. For fine crystals, or with the parallel-scanning method applied to an irregular crystal arrangement, bremsstrahlung intensifies only the darkening of the background of the picture, on which the diffracted Debye-Scherrer lines of the monochromatic rays remain clearly visible. If the sample is sufficiently coarse-grained, however, the recording, owing to bremsstrahlung, will show numerous irregularly distributed Laue spots. These dark spots are produced by the continuous (polychromatic) radiation when the number of diffracting crystals is small ; then, only a few values of angles of incidence θ are effectively available, so that, according to Bragg's equation, only individual interference spots are formed. These Laue spots may even be mistaken for parts of monochromatic Debye-Scherrer lines, if the sample is rotated without parallel scanning to cover a large number of crystals. The coarser the grain, the more marked will these Laue spots become, and the Debye-Scherrer lines will hardly be recognizable. If the irradiated portion of the sample consists of only one crystal, the possibilities of diffraction of a given wavelength λ become extremely small, and there is a definite number of angles of incidence θ, so that, despite the multiplicity of wavelengths in the bremsstrahlung, only one diffraction can take place. In this case classical Laue patterns are obtained.

If a single crystal is investigated with bremsstrahlung and a superimposed monochromatic radiation, in such a manner that its crystallographic axis forms an angle α with the primary X-ray beam, a recording is obtained in which most of the interference spots are due to the continuous X-ray spectrum, and very few, if any, are produced by the characteristic radiation. However, if this crystal is rotated about the crystallographic axis with a constant angular velocity, so that it will revolve through an angle which is a whole multiple of 2π during the exposure period, then the sets of lattice planes will no longer comprise only one incident angle θ determined by an angular attitude of the crystal relative to the primary beam, but will continuously cover a range of angles θ_1 to θ_2. Now, it is more likely that the angle of incidence of the characteristic (monochromatic) radiation according to Bragg's equation will be included in this range than when the crystal is stationary ; thus, the possibility of diffraction of a monochromatic radiation on a certain set of lattice planes is consideraly increased, although not all the angles of incidence are present, as in the case of irregular polycrystalline samples.

Consequently, with a rotated single crystal, the beams of characteristic radiation diffracted at sets of lattice planes with the same indices will not form cone surfaces which are homogeneously filled with the diffracted radiation, as in the Debye-Scherrer method, but in the best case only some of the generating lines of these lateral cone surfaces will be diffracted. Hence, instead of the Debye-Scherrer circles, interference spots only, at the radial distances of the corresponding Debye-Scherrer circles, are obtained on the diagrams. The geometric details are shown in Fig. 6. When the crystal is rotated, bremsstrahlung no longer produces interference spots but generates radial interference lines, or " asterisms ". It has been proved by the author that these asterisms are due to radiation from the continuous spectrum diffracted on sets of lattice planes rotated about an axis.

The indices of the axis of rotation can easily be determined by considering, for instance, a crystal of the cubic-lattice system rotated about a crystallographic axis [*u*, *v*, *w*], which for simplicity is arranged to be in the vertical direction. If the characteristic radiation diffracted on the set of lattice planes [*h*, *k*, *l*] forms an angle θ with the lattice plane, and the flat-film method is used, for a simple representation, then the value of θ can be calculated from

$$\tan 2\theta = r/R$$

where r = distance (Fig. 6) of the interference spot considered from the intersection of the primary beam and the plane of the film, while R = distance between the film and the point of impingement of the primary beam on the crystal. If the angle θ occurs at all in a set of lattice planes, it will be contained four times between this plane and the primary beam, in the arrangement chosen, since the plane through the (vertical) axis of rotation and the primary beam, and the plane perpendicular to this beam, are both planes of symmetry. In Fig. 6, the angle between the vertical axis and the radius vector of the inter-

* *Radex Rundschau*, No. 4, 1952, pp. 166-180, and No. 5, 1952, pp. 200-209.

ference spot of the characteristic radiation is denoted by δ. If the normal n of the diffracting plane forms with the vertical an angle ρ, use can be made of the Polanyi equation for spherical triangles (Fig. 7), i.e.,

$$\cos\rho = \cos\delta \cos\theta.$$

In Fig. 7, s_0 and s are the directions of the primary and the diffracted beams respectively, forming an angle 2θ between them. The plane through the primary beam and the vertical is at an angle δ to the plane containing the primary and the diffracted beams. The intersection point on the sphere of the lattice-plane normal is denoted by N; as the normal n, according to the law of diffraction, must be situated in the plane of s_0 and s, ND is perpendicular to DV. Hence, NDV is a right-angled spherical triangle, and the Polanyi equation can be applied.

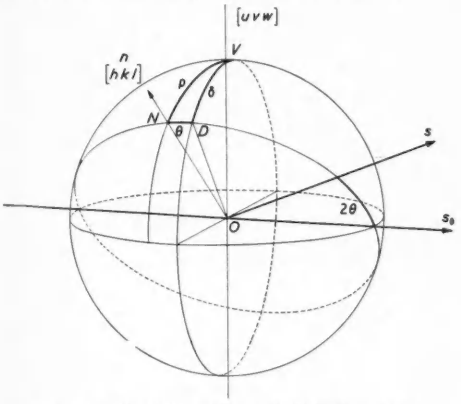

Fig. 7. **Graphical interpretation of the Polanyi equation.**

Moreover, with the relation for the cubic system

$$\cos\rho = (uh + vk + wl)/[\sqrt{u^2 + v^2 + w^2} \times \sqrt{h^2 + k^2 + l^2}]$$

where $[h, k, l]$ are the Miller indices of the diffracting planes and $[u,v,w]$ those of the axis of rotation, these can be calculated without difficulty from three independent sets of lattice planes, since ρ is determined from the Polanyi equation and the diffracting planes are generally known from the crystal structure and the value of the wavelength used. If the axis of rotation is not perpendicular, but at an angle α to the primary beam, the crystallogram will no longer be symmetrical with the vertical plane but only relative to the horizontal plane. The equations are then expanded correspondingly.

The crystallogram of a cold-drawn wire is comparable with that of a rotated single crystal, particularly if the wire has been subjected to severe drawing conditions. If the axis of the wire is at right angles to the primary X-ray beam, a diagram similar to that of the rotated single crystal is obtained, the only differences being that the interference spots are spread out as portions of Debye-Scherrer circles and the angle δ covers a certain region. Thus, on these circles accumulation points or patches, such as were first observed with natural fibrous materials (cellulose), are obtained, and for this reason these crystallograms are referred to as " fibre diagrams " and the texture is called a " fibre texture ". The common axis, which, as outlined above, can easily be calculated, at least for the cubic system, is known as the " fibre axis ". Fig. 8 shows a fibre diagram of a cold-drawn aluminium wire, obtained with perpendicular irradiation from an X-ray tube with a molybdenum anode. The schematic appearance of this diagram is analysed in Fig. 9. Comparison of Figs. 8 and 9 shows that a cold-drawn aluminium wire has the [1, 1, 1]-axis as its fibre axis. In the case of a wire of α-iron, for instance, the [1, 1, 0]-axis would adjust itself in the direction of drawing. For cold-rolled sheet, and materials with grain growth due to electrolytic action or casting, texture diagrams are also obtained, but they are not as easy to interpret as fibre textures, in which the fibre axis is an axis of symmetry.

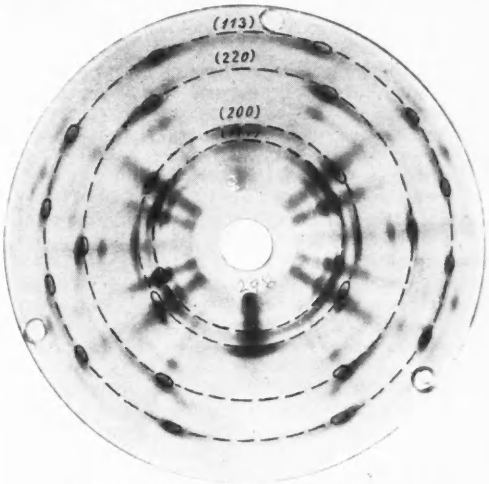

Fig. 8. **Fibre diagram of a cold-drawn aluminium wire.** The calculated positions of maximum darkening are indicated by dotted lines.

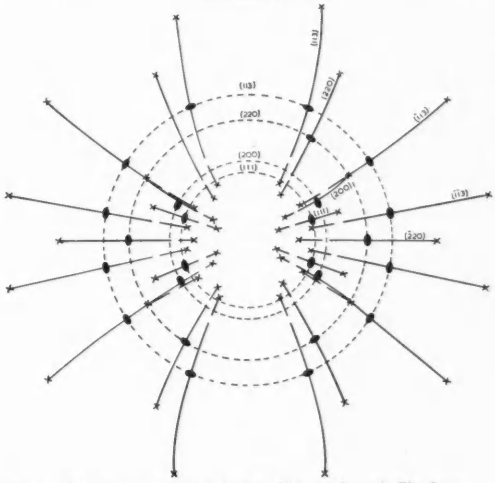

Fig. 9. **Schematic analysis of the fibre diagram shown in Fig. 8.** The starting points of the curves in the interior of the diagram are marked with a cross, and correspond to a wavelength of 0·353 A ; the outer points of these curves, also marked with a cross, correspond to a maximum wavelength of 1·000 A. The breaks in the lines correspond to the K-absorption limit of the silver in the photographic emulsion. The black spots represent interference of the Mo-K α-radiation and are connected with each other by the corresponding Debye-Scherrer circles.

The orientation of the crystallites is much more marked in rolled sheets. There is not only a determined crystallographic direction parallel to the rolling direction, but also a crystallographic plane parallel to the rolling

plane. Thus, in the case of a heavily cold-rolled iron sheet, the [1, 0, 0]-planes (cube faces) are parallel to the plane of rolling, and the [1, 1, 0] directions (cube-face diagonals) are parallel to the rolling direction. A sheet of this type gives the same effect as a single crystal divided into many uniformly oriented regions. Whereas the cold-drawn wire has its fibre axis as an axis of symmetry and can be rotated during the investigation at right angles to the primary X-ray beam without altering the diagram, the cold-rolled sheet produces diagrams of which the features, even with a rotational axis perpendicular to the primary beam, depend on the angle between this beam and the rolling plane.

In some cases, in the drawing of metal wires there occurs also a second, less numerously represented group of crystals which has another crystallographic axis as its fibre axis. For instance, wires with face-centred cubic crystals can have a fibre axis in the [1, 0, 0] direction, in addition to that in the [1, 1, 1] direction mainly represented. The crystallogram then contains both textures superimposed. In rolled textures there are frequently two crystallographic directions parallel to the rolling direction, and two planes parallel to the rolling plane. Furthermore, as various small or large deviations from the ideal case occur, it will be appreciated that the determination of a fibre texture is frequently associated with technical difficulties.

When a cold-worked metal is heated above a certain temperature, the diagrams will show small points which look like pin-pricks but which are due to regularly oriented crystals formed by recrystallization. If the temperature is increased still further, a new recrystallized texture is produced, often completely different from the rolling texture. Previously, recrystallization was exclusively associated with the concept of grain size. However, equal grain sizes are not necessarily indicative of the same recrystallization condition since, here also, the crystal orientation must be considered. Moreover, with the same cold-working treatment, the recrystallization temperature is considerably affected by small additions to the metal. As textures result in anisotropic properties, as regards strength and plasticity, they have an unfavourable effect on the mechanical properties of most metals ; on the other hand, the magnetic properties, for instance, can be considerably improved by textures, while the corrosion behaviour of metals also depends on their texture ; consequently, the study of metal texture is extremely important for technological applications.

The Cone Method

Although, in principle, the problem of the texture analysis of cold-worked metals and alloys by X-rays has been solved, there are many practical difficulties. The flat-film method, owing to the fairly small aperture angles used, permits only a certain number of lattice planes to be recorded satisfactorily. With the cone method developed by the author, much wider angles become possible. The direct cone method (Fig. 4) records all reflections on lattice planes, which make an angle of incidence θ of zero to 45 deg. with the primary beam, while the back-reflection method records all angles of incidence between 45 and 90 deg. (Fig. 5). In the evaluation, it should be borne in mind that the values of δ must be doubled, since in the cone diagram the Debye-Scherrer lines form a semicircle instead of a complete circle. For the direct cone method, the radiation is obtained from an X-ray tube with a silver or molybdenum anode ; copper or cobalt anodes are sometimes also suitable. For the back-reflection cone method, the author has, in special cases, used anodes of, for instance, 50% iron and 50% cobalt, or 50% copper and 50% nickel, with good results. The back-reflection cone method is employed where the direct method is either impossible or unsuitable, as, for instance, when it is essential that samples should not be damaged but only etched on the surface.

In texture diagrams, the use of focusing methods is unsuitable, owing to the large ranges of angles of incidence. Moreover, contrasted with the requirements for determining lattice constants or lattice dislocations, in texture determinations any relative motion of the sample with respect to the recording film has to be avoided.

It has been pointed out elsewhere by the author* that slight alterations in lattice dimensions, as well as lattice dislocations, can be determined with accuracy only by making use of the interferences with large angles of incidence, the so-called " last lines ", since these are much more sensitive to lattice-constant changes than interferences with smaller angles of incidence. For substances with considerably dislocated lattices, however, it is necessary to use small incident-angle interferences for at least approximate determinations of the lattice data, since with pronounced dislocations the last lines are frequently completely inaccessible to observations. In the particular case of marked dislocations, the loss in accuracy is a desirable feature, since under such conditions the atomic distances fluctuate and high-accuracy figures would be meaningless.

In texture investigations, both direct and back-reflection methods can be used, although under certain conditions only the latter method is applicable. The following considerations are given to enable a correct choice to be made in cases where both methods are possible, and to give some idea of the accuracy limits of the respective methods.

The case of the axis of rotation or fibre axis at right angles to the primary X-ray beam, considered above, involves the use of the Polanyi equation ($\cos\rho = \cos\delta \times \cos\theta$). Differentiating, with θ kept constant, $\sin\rho\, d\rho = \cos\theta \sin\delta\, d\delta$, so that

$$\left(\frac{d\delta}{d\rho}\right)_{\theta} = \frac{\sin\rho}{\cos\theta \sin\delta}$$

The denominator tends towards zero when $\delta \rightarrow \pi/2$; hence, the derivative $d\delta/d\rho$ increases in this case beyond all limits. It is known, however, that all the naturally occurring single crystals are mosaic crystals, in which small fluctuations do occur. The author has shown how to make use of this high sensitivity of the back-reflection method to small changes in the angle ρ in the investigation of metals, so as to obtain by his method of determining the latitude of peripheral interference points the variation of the fibre axis of the individual dendrites, even in cases of elastic or very small plastic deformation, which would hardly be possible by the direct method. However, if (as is always the case with cold-worked metals) there are considerable deviations from the ideal texture condition, then a less sensitive method should be sought, in order not to blur the recording of any slight crystal orientation owing to the high sensitivity of the azimuth angle δ to fluctuations of ρ. To sum up, the direct method shows even very slight crystal orientations, whereas the back-reflection method can be employed to record well-defined textures only. In the latter case also, the cone

* *Radex Rundschau*, No. 4, 1952, pp. 166-180, and No. 5, 1952, pp. 200-209.
"Ergebnisse der technischen Röntgenkunde", 1931.

method is superior to the flat-film method, which only records lines with an angle of incidence of nearly 90 deg.

The advantages of the direct and back-reflection procedures are combined with the recording of all interference lines over their entire length by means of the "double-cone" method, using the arrangement shown in Fig. 10. Instructive results are obtained by comparing complete double-cone diagrams of a crystal of rock-salt, taken before and after compression of the crystal. Before compression, the crystal is as clear as glass ; the direct recording shows interference spots which are typical of a Laue pattern, and which are due almost exclusively to bremsstrahlung. In the back-reflection diagram, the characteristic radiation predominates. The diffraction of the Cu-K α-radiation by several sets of lattice planes is possible because of the fact that a crystal of NaCl generally consists of small mosaic blocks which are somewhat twisted relatively to each other. The distortions appear as slight asterisms in the direct diagram. In the back-reflection diagram, the small width of the interference spots shows that there are no deviations from the ideal texture of the mosaic blocks in the single crystal. After compression, the crystal has a cloudy appearance. Instead of Laue patterns, only asterisms occur in the direct diagram, thus indicating considerable buckling of the crystallographic axes of the small mosaic crystals, although the overall locations are unchanged. This evidence is further confirmed by the appearance of portions of Debye-Scherrer lines in the back-reflection diagram. These lines are now much wider than previously in the peripheral direction and thus indicate a deviation from the ideal crystal arrangement about a preferred axis. Evidently, this twisting of the mosaic blocks is also the cause of the cloudiness of the crystal.

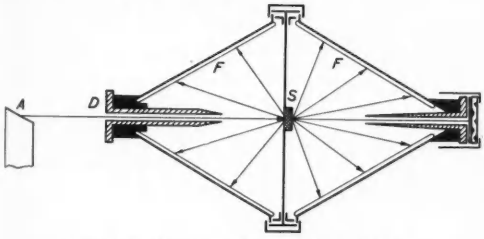

Fig. 10. Double-cone method, according to Regler.

The double-cone method, as the above example shows, is of considerable value in non-destructive texture investigations.

The Sweeping-Beam Method

The methods described above give sufficient information on most deformed textures without subsequent recrystallization. If, however, a recrystallization texture occurs, as is very often the case, for instance with high-purity aluminium, it is frequently no longer possible to recognize the crystal orientation in the crystallogram. Usually, the diagram then shows Laue patterns with such an irregular confusion of relative positions that it is impossible to deduce anything about the crystal arrangements in the material, i.e., in regard to the relative positions of the large grains. Furthermore, a diffraction of the characteristic radiation on these few crystals cannot be obtained with certainty, so as to determine their positions from the Polanyi equation, as well as the angles between the normals of the lattice planes and the axis of orientation, and to evaluate therefrom the indices of the preferred direction. In such cases, even the best data have been built up on supposition.

For a successful analysis of recrystallization textures, it is necessary to enlarge considerably the irradiated volume of the sample. For this purpose, it might be possible to try to increase the diameter of the primary X-ray beam or the thickness of the sample, at least for direct recordings. However, both these possibilities give only moderately successful results. As there are no technically suitable lenses in the range of wavelengths of X-ray radiation, an increase in the diameter of the primary beam to values above, say, 1 mm, results in such a deterioration of the image-forming conditions that the use of an aperture diameter of 1·5 or 2 mm seems possible only in very rare cases. Increased thickness of the sample cannot be considered because of the associated absorption losses. The only effective means of increasing the extent of the irradiated volume is provided, therefore, by the "scanning" or "sweeping-beam" method.

Parallel scanning could be used without any difficulties in the case of an ideal fibre texture (e.g., a texture obtained by drawing), since the fibre axis, being an axis of symmetry, would appear to permit a rotation of the sample about this axis and also a parallel displacement in the axial direction. In commercial metals, however, ideal fibre textures are very rare. Frequently, there are even two fibre axes, and in rolling textures, for instance, the rolling direction is no longer an axis of symmetry about which it is possible to rotate the sample to increase the number of diffracting crystals. On the other hand, from a consideration of Fig. 6, it is evidently possible to rotate the sample and the film simultaneously about the primary beam as axis, without altering the appearance of the diagrams. However, this does not increase the magnitude of the irradiated volume of the sample.

The new method proposed by the author consists of providing for synchronous rotation of the film and the sample, as mentioned above, but with the two parallel axes placed eccentrically to each other, as shown in Fig. 11. In this arrangement, which, however, requires homogeneous texture conditions within the region being scanned, the primary X-ray beam becomes diffracted on a hollow cylinder with a circular base and a very short length ; its wall thickness is determined by the aperture diameter, and its mean radius by the distance of the two axes of rotation of the apparatus. This sweeping-beam method makes it possible to increase the number of crys-

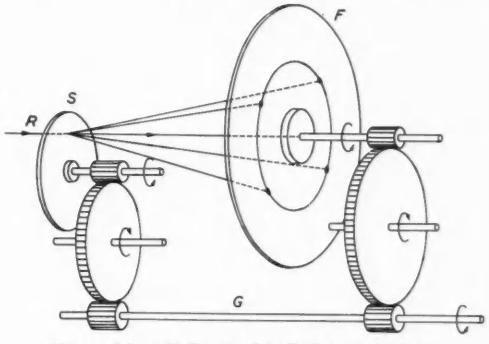

Fig. 11. Schematic diagram of the Regler sweeping-beam method.
(*R*) Primary X-ray beam from anode via diaphragm; (*S*) sample; (*G*) synchronous drive; (*F*) film.

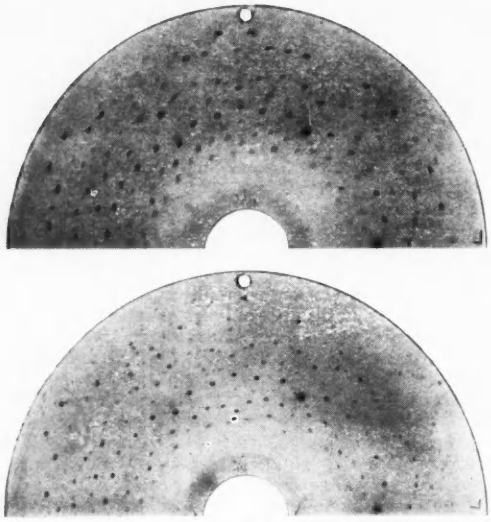

Fig. 12. Recordings of a quartz crystal, obtained (above) by the direct stationary-cone method, and (below) by the direct sweeping-beam method.

tals by increasing the relative distance between the two rotating axes. The new method, in principle, is equally suitable for cone and flat-film diagrams, with direct or back-reflection recording.

The suitability of this method will now be verified by considering typical diagrams, in the first place those of single crystals free from defects. An interesting comparison is given in Fig. 12, which shows recordings of a quartz crystal obtained by the direct stationary-cone method and the direct sweeping-beam method respectively. The sample had a thickness of 0·5 mm and was irradiated parallel to its *z*-axis with a beam from a molybdenum anode. The cylindrical diaphragm for the primary beam had a diameter of 0·4 mm. For the sweeping-beam method, a distance between the axes of 2 mm was chosen. In both recordings, the crystallographic direction is exactly the same, within the limits engendered by inevitable fine-structure defects, and applies to direct and back-reflection diagrams. The similarity in appearance of the two recordings is very good, and some experience is needed to notice the widening of the Laue spots, particularly in the peripheral direction, in the diagram made by the sweeping-beam method, caused by the mosaic structure of the crystal when scanning a larger volume of the sample. A sweeping-beam back-reflection diagram of the quartz crystal is shown in Fig. 13, and is identical in appearance with the corresponding diagram obtained by the stationary-cone method.

It was not possible to make a sufficiently large plate from a crystal of rock-salt free from defects, as required for the sweeping-beam method, for a similar comparison. Therefore, comparative recordings were taken only with back reflection. The recordings obtained by the stationary-cone method and the sweeping-beam method show no discernible differences.

In order to make a complete comparison for single crystals, flat-film back-reflection investigations were also made with a spectrometer crystal of calcite. In these recordings, an aperture diameter of 0·8 mm was used, and the distance between the two rotating axes of the sweeping-beam apparatus was set at 5 mm. The radiation was obtained from an X-ray tube with a cobalt anode. The diagram recorded by the sweeping-beam method is shown in Fig. 14, and was virtually similar to the corresponding stationary diagram.

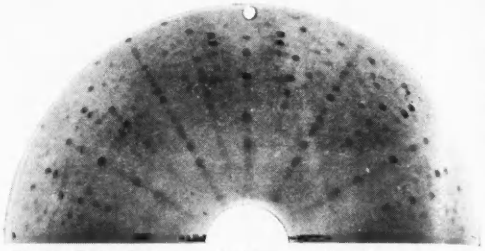

Fig. 13. Back-reflection sweeping-beam recording of a quartz crystal.

It is now important to consider the image obtained by the sweeping-beam method with a deformed NaCl crystal which has become clouded under a load of 550 kg/cm². If it can be assumed that the investigated region of the crystal was homogeneously deformed, it would be reasonable to expect that the diagrams made by the sweeping-beam method and by previous methods will be in good agreement. This is actually the case. A double-cone sweeping-beam diagram of the compressed NaCl crystal is shown in Fig. 15.

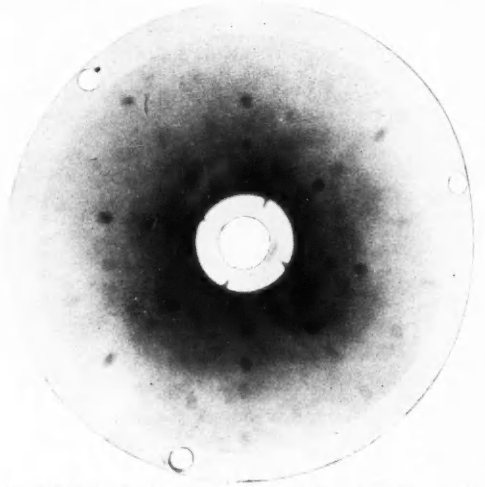

Fig. 14. Back-reflection sweeping-beam recording of a calcite crystal.

The above results show that the sweeping-beam method causes no alterations in the crystallograms of normal or deformed single crystals, i.e., it indicates only the true properties of single crystals, without additional misleading features. The next application of this method is in the texture investigation of recrystallized samples.

A sheet of pure aluminium, rolled down to a thickness of 2 mm, was irradiated with molybdenum radiation (tube voltage 45 kV) and investigated by the direct stationary-cone method. The sample, with a thickness of 0·4 mm, was taken from the internal layers of the sheet. An aperture of 0·4 mm diameter was employed. The stationary-cone image is reproduced in Fig. 16, and shows considerable clusters of Laue spots and signs of asterisms. This is a typical recording for coarse-grained

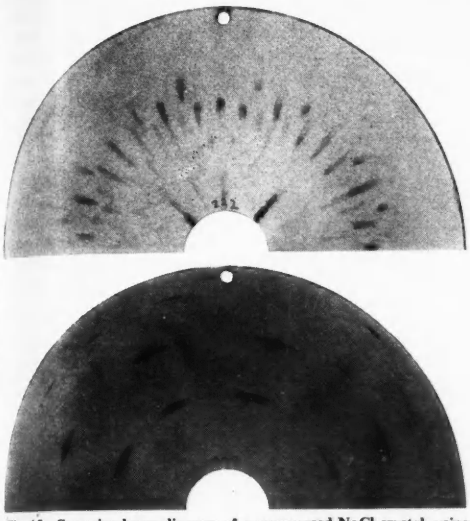

Fig. 15. **Sweeping-beam diagram of a compressed NaCl crystal, using the double-cone method, showing (above) the direct recording, and (below) the back-reflection recording.**

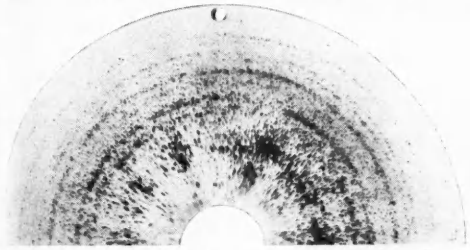

Fig. 16. **Direct stationary-cone diagram of a recrystallized sample of aluminium.**

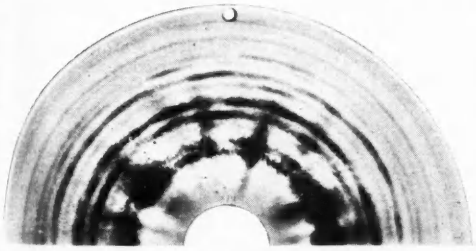

Fig. 17. **Direct sweeping-beam diagram of a sample of aluminium, as in Fig. 16, but with a larger aperture.**

metals, and also shows Debye-Scherrer lines resolved into points. The distribution of the darkened areas and interference lines, however, is so confused that a definite determination of the texture is hardly possible. With the sweeping-beam method, the corresponding diagram shows, instead of the Laue spots, regularly arranged asterisms (due to bremsstrahlung) and Debye-Scherrer lines (produced by the Mo-K series) with symmetrically arranged darkened areas. It presents the technical details required for texture evaluation. To assess the influence of an increase in aperture diameter from 0·4 mm to 1 mm on the result, the above investigation was repeated with a larger aperture. The resulting diagram obtained by the sweeping-beam method is shown in Fig. 17. The increased aperture size caused no appreciable alteration of the image and, in this case also, only the sweeping-beam diagram is suitable for evaluation.

Further comparisons of this kind were made with a sample of recrystallized aluminium taken from the surface of the rolled aluminium sheet. The recrystallization was less marked than with the previous sample, so that the evaluation of the stationary diagram does not seem quite impossible. The results again indicate that the sweeping-beam method gives a considerable improvement.

An improvement is also obtained with back reflection. The cone method used for a stationary diagram of a recrystallized aluminium sample produced an image in which the Debye-Scherrer lines were already resolved into points, with darkened areas, but the corresponding sweeping-beam diagram shows continuous dark rings which are much more clearly defined (Fig. 18). The recordings were taken with Cu-K radiation in this instance and a cylindrical aperture of 1 mm diameter, with a distance of 5 mm between the rotating axes of the sweeping-beam apparatus. Fig. 18 shows the remarkable advantages of the sweeping-beam method, with eccentric axes of rotation, over the ordinary scanning method or the method providing only for a rotation of the sample relative to the film while maintaining the axis of rotation

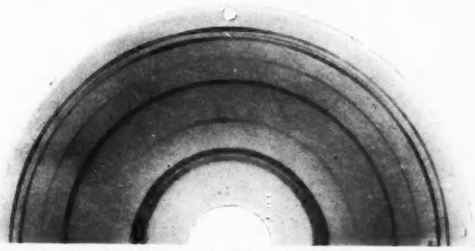

Fig. 18. **Back-reflection sweeping-beam diagram of a recrystallized sample of aluminium.**

unchanged. In both the latter methods, the lines are homogeneously darkened, but the dark patches caused by the texture are lost. With the sweeping-beam method, the separate interference spots which cannot be assessed are merged into each other, but the darkness maxima and minima on the lines remain intact.

Consequently, the advantage of the sweeping-beam method with eccentrically rotated axes is that it increases the number of crystals investigated, without changing the interfence patterns caused by the relative crystal orientation. All the Laue spots, which are merely disturbing in texture evaluations, disappear, as in ordinary investigations with polycrystalline fine-grain samples. However, if the grains are rotated in such a manner as to produce the effect of a single crystal, the Laue spots are clearly distinguishable. The monochromatic radiation can also be diffracted by many grains in the sample. With a random crystal arrangement, the result is a homogeneous darkening of the image, whereas with texture diagrams the corresponding Debye-Scherrer lines produce distinctly darker areas. Finally, for single crystals, the sweeping-beam method, owing to the increased diffracting volume of the crystal, is particularly suitable for indicating defects in lattice structure. If the crystal elements are warped, this becomes immediately apparent, because the sweeping-beam diagram and the stationary diagram are then no longer identical.

HOLLAND

Stresses in Pressure Vessels

By W. P. KERKHOF. (From *De Ingenieur*, Vol. 67, No. 45, November 11, 1955, pp. W.131-W.138, and No. 46, November 18, 1955, pp. W.141-W.148, 16 illustrations.)

(Concluded from February issue)

(15) Allowable Stresses for Cylindrical Shells between Atmospheric Temperature and 343°C

It is recommended that the fraction of the yield point for calculating the allowable membrane stress should increase gradually from 0·60 at atmospheric temperature to 0·72 at 343°C. It is difficult to calculate the equation for this decrease. As a first approximation, however, a straight-line relation will be chosen, this being simple and probably accurate enough.

The stresses proposed are shown in Table II, in which σ_y is the hot yield point.

Table II : Design Membrane Stresses in Cylindrical Shells.

20°C	75°C	130°C	185°C	240°C	295°C	350°C
$0{\cdot}60\sigma_y$	$0{\cdot}62\sigma_y$	$0{\cdot}64\sigma_y$	$0{\cdot}66\sigma_y$	$0{\cdot}68\sigma_y$	$0{\cdot}70\sigma_y$	$0{\cdot}72\sigma_y$

(16) Local Out-of-Roundness

The allowable membrane stresses given in Table II can be safely adhered to only if the out-of-roundness is limited in accordance with Fig. 3. For measuring the out-of-roundness the length of the cylinder should be subdivided into parts, each having a length of $\frac{1}{4}D$ (Fig. 7), and the out-of-roundness of each part should be found, as described in section 7. The combination of five values giving the greatest mean value of the out-of-roundness occurring over a length of the cylinder equal to the diameter can then be calculated. According to Fig. 7 the greatest mean value is

$$h_m = \tfrac{1}{4}\,(\tfrac{1}{2}\,h_4 + h_5 + h_6 + h_7 + \tfrac{1}{2}\,h_8) \quad .. \quad (14)$$

This calculated mean value must be below the limit shown in Fig. 3. Such measurements have been carried out by the boiler-inspection authorities in the Netherlands for many years and present no difficulty at all.

Attention is drawn to the fact that the greatest mean value of the out-of-roundness, as occurring over a certain length of the cylinder, is measured, and not the maximum value h_6 in Fig. 7. This is logical, because the theory under consideration refers to stresses over a large area.

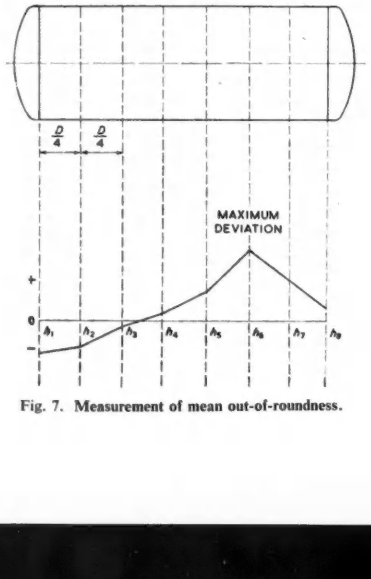

Fig. 7. Measurement of mean out-of-roundness.

The maximum out-of-roundness can be considered as producing local stresses, so that here the theory as enunciated in sections 10 and 11 applies. Consequently, for the maximum out-of-roundness eq. (8) has to be used, assuming $\alpha = 1$, and for the mean out-of-roundness eq. (12a) (at 343°C). The total stress at a spot characterized by local out-of-roundness may thus be $1{\cdot}75/1{\cdot}20 = 1{\cdot}46$ times the mean stress. A local out-of-roundness giving an increase in stress of 46% over the mean value defined above seems to be very unrealistic. Consequently, measurement of the mean out-of-roundness gives, at the same time, a safe limit for the local out-of-roundness.

(17) Simplications and Extra Safety Relative to Fatigue

The necessity for uniformity in calculation has already been mentioned. One simplification has been made by ignoring eq. (2a) for the local stresses. As eq. (2a) is suitable for boilers and some pressure vessels, but not for all pressure vessels, the local stresses in boiler-type vessels may be higher. Eq. (1), however, is the same for all types of vessel. For the sake of uniformity eq. (2b) has been chosen, as being applicable to the more severe cases. Consequently, the domed ends of boilers are considered as being less severely loaded than those of some pressure vessels; the cylindrical shells, however, have to be stressed to the same value in both cases.

Another simplification is proposed. From consideration of the allowable membrane stresses (design stresses) in the cylindrical shell, as shown in Table II and eq. (8) for domed ends, it follows that the allowable stress in domed ends is about $2{\cdot}4\alpha$ times the design stress at 343°C, and $2{\cdot}9\alpha$ times the membrane stress at atmospheric temperature.

According to the conventional method, it is usual to relate all stresses to the design membrane stresses. The advantage of this method is that only one design stress-temperature curve for a certain material must be given. If the conventional method is again followed, the local allowable stress should be some multiple of the design membrane stress, which is independent of the temperature. For the sake of safety the lowest factor must be chosen. The design membrane stress is given in Table II. The allowable local stress raiser can now be calculated by multiplying the design membrane stress according to Table II by the factor $2{\cdot}40\alpha$, or

$$\sigma_{\text{tot } L} = 2{\cdot}40\,\alpha\,\sigma_{m'} \quad .. \quad .. \quad (15)$$

where $\sigma_{\text{tot } L}$ is the magnitude of the local stress range and α a factor dependent on the accuracy of the formula used.

Recent investigations into high strain fatigue[5] have shown that the fatigue properties may be considered to be constant up to 343°C. As the yield point has its greatest value at atmospheric temperature, the lowest safety factor relative to fatigue is available at this temperature. By making the allowable stress range as proposed, all usual carbon steels and alloy steels are safe from high strain fatigue.

(18) Calculation for Domed Ends

As mentioned in section (12), most experience in the

American oil industry has been obtained with ellipsoidal heads. In Europe, high-stressed boilers and pressure vessels have basket-handle-shaped ends, in which the stresses are nearly the same as in ellipsoidal heads. As far as is known, rupture has never occurred. On the other hand, as regards shallow heads, corrosion has sometimes been found in the knuckle radius. The conclusion is that heads having a depth-to-diameter ratio of about 0·25 are safe if calculations are carried out in the normal way, but that heads having a smaller depth-to-diameter ratio are sometimes stressed too highly, judging from the local corrosion found. If this conclusion is true, it should be possible to corroborate it with the help of the above theory.

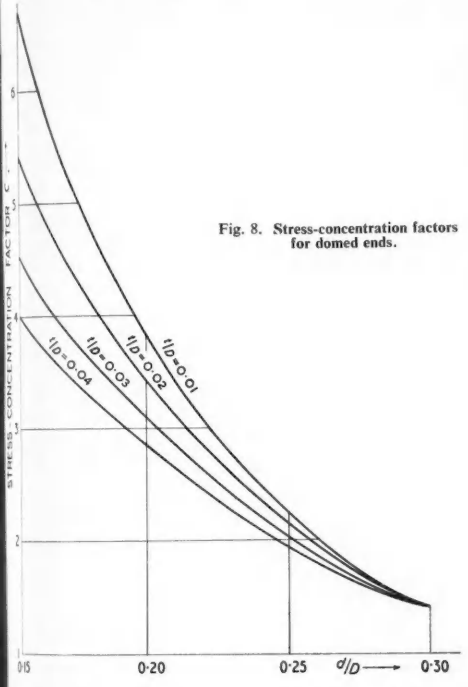

Fig. 8. Stress-concentration factors for domed ends.

The exact calculation of stress in domed ends is too complicated for normal use. For the time being, the following approximation is proposed

$$\sigma_{\text{tot } L} = C\frac{PD}{2t} \quad .. \quad .. \quad .. \quad (16)$$

where P is the internal pressure, D the external diameter of the vessel, and t the thickness of the head. As a result of many measurements, Carlson and McKean[8] drew up curves for C, as shown in Fig. 8. C is dependent on the t/D ratio and the d/D ratio, where d is the external depth of the head. The factor C is given in such a manner that $\sigma_{\text{tot } L}$ equals the equivalent uni-axial stress according to the shear strain energy theory.

According to section 17, eq. (15) can be written

$$2{\cdot}40\,\alpha\sigma_m' = C\frac{PD}{2t} \quad .. \quad .. \quad (17)$$

where σ_m' refers to the design stress.

Carlson and McKean[8] also calculated the stresses and, from the resulting deviations, the factor α is estimated to be about 0·80, so that eq. (17) can be written

$$\sigma_m' = \frac{C}{2}\frac{PD}{2t} \quad .. \quad .. \quad .. \quad (18)$$

Comparisons of the value of $C/2$, according to Carlson and McKean, were made with the same value according to the A.P.I.-A.S.M.E. code and the Swedish pressure-vessel code for the usual head shapes. The comparison with the A.P.I.-A.S.M.E. code is included because this code permits a stress at 650°F (343°C) of $0{\cdot}72\,\sigma_{y343}$, i.e., the value given in Table II. The Swedish code permits 67% of the hot yield point, but in no case does it allow more than 67% of the yield point at 150°C. According to the new proposal (Table II), 67% of the yield point is allowed at about 200°C. Furthermore, 67% of the yield point at 150°C will be very close to 60% of the yield point at atmospheric temperature, as recommended in Table II. There are thus three temperatures at which a comparison between established practice and the proposed theory is possible.

As the $C/2$ value is proportional to the head thickness, it follows that eq. (18) gives thicknesses for ellipsoidal and basket-handle-shaped heads which are practically the same as those calculated with the formulae of the codes mentioned. According to the same table, the thin-walled shallow heads should be thicker than according to the codes referred to. This is in agreement with the experience mentioned, i.e., that corrosion sometimes occurs in thin-walled, shallow heads.

As there is now very good agreement between the findings of the theory and the results of established practice at atmospheric temperature, 200°C, and 343°C, this comparison is also a proof that the theory as a whole is in conformity with good practice.

(19) Calculation for Parts other than Domed Ends and Cylindrical Shells

The general equations for all parts of pressure vessels will be

(a) for local stresses eq. (15), and

(b) for stresses distributed over a large area

$$\sigma_{\text{tot}} = C\alpha\sigma_m' \quad .. \quad .. \quad .. \quad (19)$$

The value σ_m' in these equations is the stress tabulated in Table II, i.e., the design membrane stress in the cylindrical shell, or the design stress. The real membrane stress σ_m occurring in some part of the vessel is different from σ_m'.

The factor α indicates the accuracy of the strength formula to be used. C can be calculated with the aid of eq. (1), as follows :—

Assuming that $\sigma_b/\sigma_m = K$, eq. (1) can be written

$$\sigma_m = \left\{\sqrt{\tfrac{1}{9}K^2 + 1} - \tfrac{1}{3}K\right\}\sigma_y \quad .. \quad (20)$$

which means that at the above value of σ_m yielding takes place throughout the total plate thickness of the part under consideration. The total stress is

$$\sigma_b + \sigma_m = (K+1)\,\sigma_m = \sigma_{\text{tot}}$$

or $$\sigma_{\text{tot}} = (K+1)\left\{\sqrt{\tfrac{1}{9}K^2 + 1} - \tfrac{1}{3}K\right\}\sigma_y \quad .. \quad (21)$$

According to eq. (11), yielding takes place throughout the whole plate thickness of the cylindrical shell if

$$\sigma_m' = 0{\cdot}81\sigma_y \quad .. \quad .. \quad .. \quad (22)$$

From eqs. (21) and (22), it follows that

$$\sigma_{tot} = \frac{(K+1)}{0{\cdot}81}\left\{\sqrt{\tfrac{1}{3}K^2+1} - \tfrac{1}{3}K\right\}\sigma_m' \quad .. \quad (23)$$

Neglecting α in eq. (19), it follows that

$$C = \frac{(K+1)}{0{\cdot}81}\left\{\sqrt{\tfrac{1}{3}K^2+1} - \tfrac{1}{3}K\right\} \quad (24)$$

If only bending stress occurs ($\sigma_m = 0$),

$$\sigma_b = 1{\cdot}85\,\alpha\sigma_m' \quad .. \quad .. \quad .. \quad (25)$$

If eqs. (15), (19), (24), and (25) are used, the safety limit is the same for all parts. Furthermore, the conventional method, in which all stresses are based on the design membrane stresses, is followed.

Eq. (15) should be used for domed ends with a depth-to-diameter ratio not exceeding, say, 0·3. For spherical ends eqs. (19) and (24) should be used, because the stresses are distributed over a large area.

In the centre of flat ends, square headers, and boxes a non-permissible deformation seems possible. Eq. (25) is therefore recommended for application to this part. At the edges of flat ends, square headers, and boxes the stress is very local, so that eq. (15) is recommended for such cases. Near nozzles the stress is local, so that eq. (15) also applies here.

(20) Comparison with Various Requirements of Existing Codes and Established Practice

It has already been shown that the theory is in agreement with the A.P.I.-A.S.M.E. code for cylindrical shells and domed ends at a temperature of 343°C. Furthermore, it is in satisfactory conformity with the Swedish pressure-vessel code for cylindrical shells and domed ends at atmospheric temperature and at 200°C. According to the German and Italian codes, the design stress is two-thirds of the yield point, resulting in a curve giving slightly higher values below 200°C, and lower values above 200°C, than those proposed for cylindrical shells. The thickness of domed ends according to the Italian code is about the same as proposed here.

The differences between the stresses in the cylindrical shell in the new Netherlands code and the proposed stresses are very small, and can be ignored. In this code, too, similar requirements for out-of-roundness are given. Consequently, the proposals discussed are in good agreement with established practice. The only difference between the proposals and the provisions of existing codes is that the former give more accurate rules for the allowable stresses for every possible stress distribution.

A weld efficiency of 100% is permitted in Germany and Holland in some cases, but not for non-stress-relieved vessels.

The membrane stress permitted in the welds of storage tanks is about two-thirds of the yield point, being about the same value as proposed here with a weld efficiency of 100%. Rupture in storage tanks does not occur, apart from brittle failure due to low temperatures. In service the shells of storage tanks corrode. It is known that corroded plates are replaced by new plates, after the membrane stress has increased to slightly below the yield point. Furthermore, many tanks are loaded and unloaded at least once a day. Consequently, there is very good experience with non-stress-relieved vessels subjected to even higher stresses than those proposed and of the same shape. The proposed value of the weld efficiency of 100% for non-stress-relieved vessels is thus fully justified.

In section 12 it was proved that the stress range in the hub of a flange in the cold condition is greater than $2\sigma_y$. The maximum stress is then greater than σ_y since some strain-hardening has occurred because of the high stress range. During heating-up the stress has to follow the yield-point curve.

A weld nearly always occurs in the hub at the spot where the stress has this maximum high value. The stresses in this weld are thus equal to or greater than the yield point at the temperature under consideration; the stress range is at least twice the yield point. Consequently, this weld is loaded in exactly the same manner as allowed according to the theory developed. As far as is known, rupture has never occurred in a hub.

This means that, without realizing it, the boiler and pressure-vessel maker has used stresses up to the yield point with 100% weld efficiency for stress-relieved and non-stress-relieved, radiographed, and non-radiographed vessels for many years with excellent results. The high stresses proposed and the high weld efficiency are thus based on established pressure-vessel practice.

(21) Conclusions

Among others, the following conclusions are drawn :—

(a) For the usual boiler-plate steels, the allowable stresses relate only to the yield point of the material. Only in exceptional cases (at low temperatures) must the fatigue strength be taken into account.

(b) The value of the allowable stress is dependent on whether or not the stress is local, on the stress distribution over the plate thickness, and on the (hot) yield point in tension and compression.

(c) No safety factor is required. The allowable stress can be calculated, taking into account the stress relaxation at high temperatures, temperature stresses, pressure accumulation during blowing of the safety device, test pressure, and the accuracy of the strength formula used.

(d) The use of a weld efficiency factor is not justified. There is reason to suppose that, within the given limits, the higher is the allowable stress, the safer is the vessel.

(e) The high allowable stresses in the cylindrical shell require more precise limitations of local out-of-roundness.

(f) The theory proposed is in agreement with good practice, experience, and the investigations.

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(7) Welding Research Committee of Inst. Mech. Eng., 1936, *Proc. Inst. Mech. Eng.*, Vol. 133, p. 5, Second Report.

(8) W. B. Carlson and J. D. McKean : " Cylindrical Pressure Vessels ; Stress Systems in Plain Cylindrical Shells and in Plain and Pierced Drumheads ". Inst. Mech. Eng., 1954, Advance Copy.

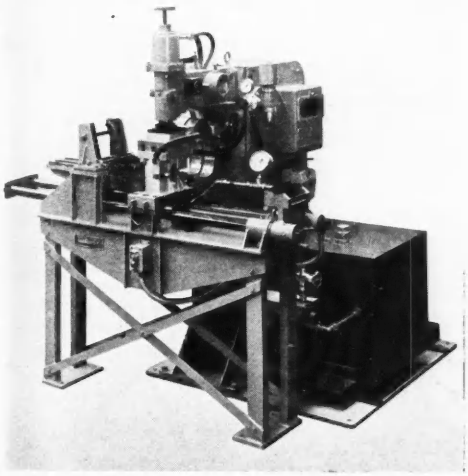
Erratum

In part II of this article in our February issue, the caption to Fig. 6 on page 66 should read " Influence of stress relaxation on local stresses ".

British Industrial Developments

Air-Operated Automatic Spot-Welding Machine

A new type of air-operated automatic spot welder, for the high production of brick force reinforcement fabric now used in quantity in the building trade to strengthen lintels, walls, etc., has recently been developed by Sciaky Electric Welding Machines Limited, of Slough, Bucks. Hitherto, this fabric, which usually consists of two 12-gauge cross-wires, has been produced by fusion or single-head spot welders; to increase output a special fixture was designed for attachment to a standard high-speed air-operated spot welder, model PMO, rated at 30 kVA. Some thirty welding strokes a minute, totalling 60 welded joints, can be achieved by this equipment, which merely requires supervision by an unskilled operator.



Basically, the fixture comprises a hydraulically operated shuttle mechanism for indexing the fabric through the machine at the correct cross-wire pitch ; a magazine which automatically feeds the cross-wires onto the shuttle mechanism ; and water-cooled electrode dies which produce two welds simultaneously on the direct/parallel system of welding. Initially, the main or longitudinal wires are fed through guides to the electrode position, and the magazine (on the left of the illustration) is loaded with cross-wires which have been previously straightened and cropped to length. The first set of joints in a production run is welded by a step-by-step arrangement, in order to pilot the automatic indexing system. After these wires are welded, the machine continues to attach cross-wires automatically to the main wires and to index the fabric at the required pitch, as long as the material is fed to the machine.

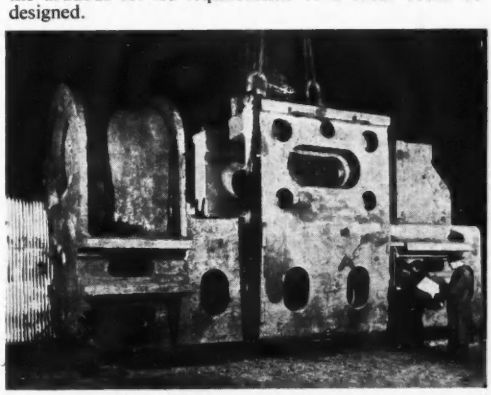
The indexing stroke is developed by a double-acting hydraulic cylinder fed by a self-contained pump and tank unit attached to a base-plate integral with the machine. The distance between cross-wires, normally 12 in., is adjustable by means of limit switches actuated by the travel of a spring-loaded pawl arrangement located on the right-hand side of the machine. Twin pawls engage on the previously welded wire and draw the entire fabric through the machine at the required distance. Electrodes are manufactured from high-grade chrome-copper alloy, and are of the bar design with wedge adjustment which will accommodate main wires spaced at 2, 3½, or 6 in. centres without any alteration to the fixture. Adjustment is also available on the magazine to correspond with variations in fabric width. The timing circuit is fully electrically interlocked, and the welding sequence is initiated by the depression of an electrical push-button.

Although the plant illustrated was designed for the production of a specific type of wire reinforcement, it could well be adjusted to produce other wire goods, providing the mesh dimensions are constant and the cross-wires are not less than 14 s.w.g.

Complicated C-Frame Casting

One of the most complicated heavy steel castings ever attempted in Great Britain has just been delivered by English Steel Castings Corporation, Ltd., of Sheffield, a subsidiary of English Steel Corporation, Ltd., to the Darnall Works of Davy and United Engineering Company Ltd., of Sheffield. Measuring approximately 26 ft in length, 12 ft in width, and 8 ft in depth, the casting (illustrated) is a 142-ton C-frame for the 1350-ton shear which Davy-United are building for Dorman Long as part of a contract for a new blooming and slabbing mill plant at Lackenby.

Despite the many technical problems involved in making this particular casting, owing to its complexity of varying wall thicknesses and shapes, it was decided that a casting made in one piece was the only possible method of manufacture, since neither a fabricated structure nor two or three separate castings capable of meeting the arduous service requirements of a shear could be designed.



The mould, with its very complicated arrangement of 80 cores, was made in a pit measuring 35 ft in length, 17 ft in width, and 10 ft in depth. These preliminaries accounted for 1240 man-hours in moulding and closing and 600 in coremaking and fitting. To dry out the moulds took another four weeks. The climax of these preparations was the casting operation when, in half an hour, three ladles simultaneously poured a total of 198 tons of molten steel into the mould.

For the pouring operation, practically the whole of the foundry's steelmaking resources were required, and for the bulk of the steel three Siemens open-hearth furnaces had to be tapped simultaneously. The casting was left in the mould for four weeks to cool, after which hydraulic jacks and cranes were used to lift it from the pit before fettling and heat treatment.

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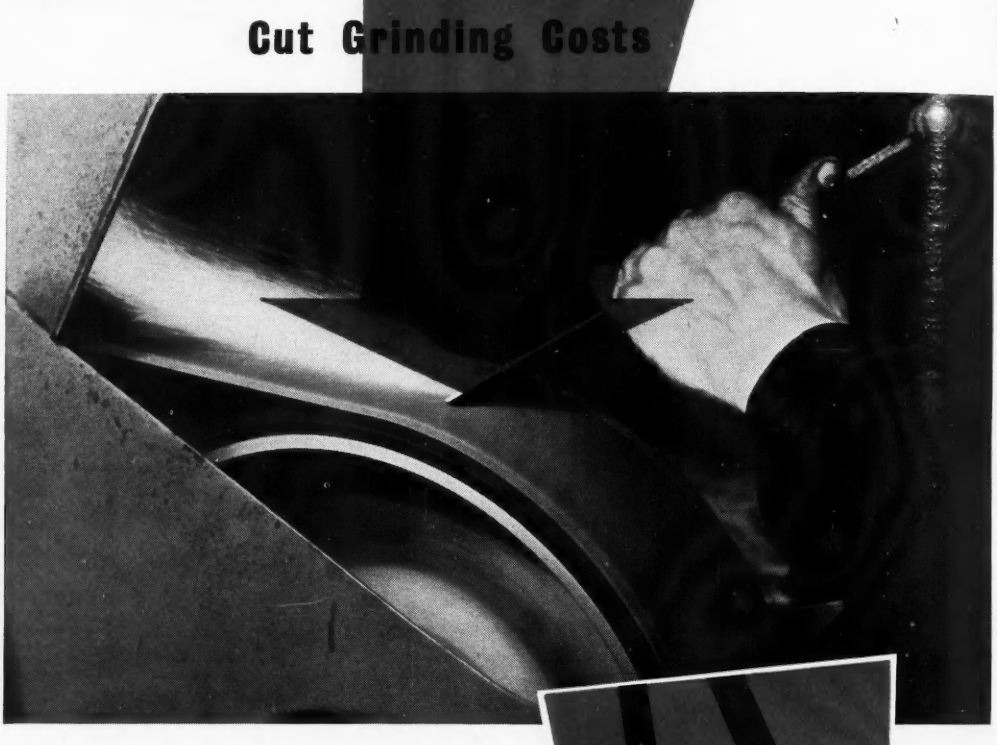

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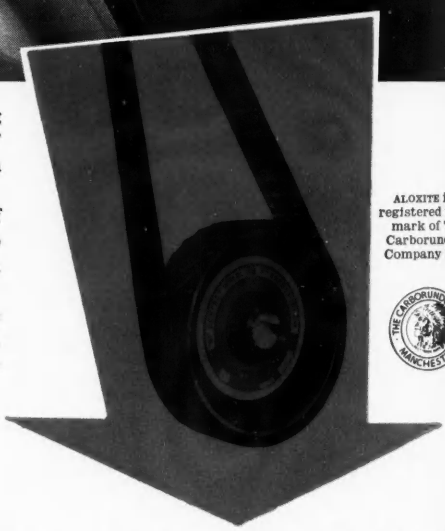

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Blue Glasses for Steelmakers

Traditionally, a blue glass of the cobalt type has been used by steelmakers when inspecting furnaces. The requirements of these glasses have been that they should be dark enough to reduce glare in the furnace to an acceptable level and that they should be of such a colour that the operator can judge accurately the temperature of his furnace. For this second requirement, a cobalt blue glass is ideal, since it has a high red and a high blue transmission and absorbs strongly the green and yellow. It therefore enables the operator to estimate temperatures quite accurately, using the two-colour pyrometry effect. Use of the filter has, however, attendant hazards, in that the glass transmits strongly in the ultra-violet and near infra-red regions of the spectrum.

At the request of the British Iron and Steel Research Association, Chance Brothers have developed a new glass, designated CSS, which is a compromise between the cobalt glass, with its properties of high temperature discrimination, and a green glass with very poor temperature discrimination, but good protective properties. The new glass provides good protection against ultra-violet and infra-red radiation, its total heat transmission being 0·05%.

Measurements have been made by the National Physical Laboratory of the efficiency of this glass as a means of estimating temperature differences. It was found that, with a CSS filter, 2·0 mm in thickness, the number of detectable chromaticity steps between a black-body radiator at a temperature of 1750°K and one of 2000°K is 61. The corresponding number of steps for a cobalt blue glass of similar total transmission is 82.

Combined Turbine Gear Hobber and Shaver

A range of new dual-purpose machine tools, the first in the world capable of both hobbing and shaving large turbine gears, is announced by David Brown Industries Ltd., Machine Tool Division, of Manchester. The full range of new machines is capable of producing turbine gears from 60 to 175 in. diameter, and pinions and first reduction wheels from 6 to 60 in. diameter.

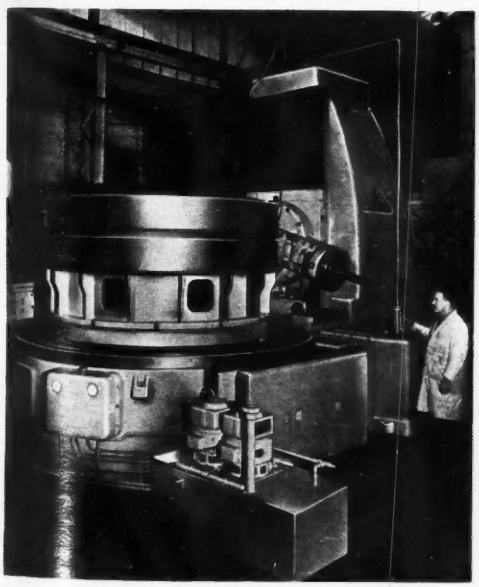

Fig. 1.

The ability to carry out both the hobbing and shaving processes successively on one machine has many obvious advantages. One machine and one operator can, if necessary, perform both operations, thereby eliminating the need for a second machine and operator and thus freeing floor-space for additional production. Furthermore, the inevitable delay, often of several hours' duration, incurred with current practice in transferring a large gear after hobbing and setting up the shaving machine to match, is eliminated. With these dual-purpose machines, after completion of the hobbing process the hob is replaced by a shaving cutter attachment. Thus, the one machine can be kept fully employed.

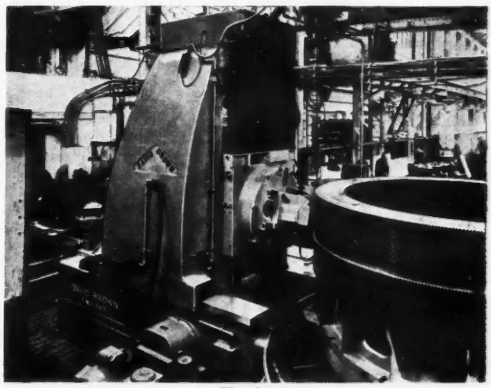

Fig. 2.

Four versions of the combined hobbing and shaving machine have been developed, designated the P60S, MH100S, MH150S, and MH175S respectively, the numeral in each case indicating the maximum diameter, in inches, of the gear which the machine can accommodate. All these machines are basically similar, and the hobs and shaving cutters designed for use with them are supplied by the David Brown Tool Division, of Huddersfield. The machine illustrated in Fig. 1 is the MH150S, which weighs 71 tons and will hob and shave gears from 70 in. to 150 in. in diameter with a maximum pitch of 2 D.P. and a maximum face-width of 70 in. The table is 133 in. in diameter, the index wormwheel is 120 in. in diameter, and the machine occupies a floor-space of 24 ft 2½ in. by 15 ft 6 in. Fig. 2 is another view of the MH150S, showing the shaving cutter attachment in use.

Automatic Self-Priming Pumps

Covering units from 1½ to 8 in. branch sizes and outputs from 30 to 1600 gpm, the " G " series of automatic self-priming pumps recently introduced by Sigmund Pumps Limited, of Team Valley, Gateshead, has been specially developed to meet the demand for an efficient and reliable self-priming pump suitable for a wide range of low- and medium-head industrial pumping applications, and to overcome the difficulties encountered with the conventional type of centrifugal pump.

Features of the " G " series of pumps include quick and automatic priming, combined with efficient pumping. Once primed, no liquid circulates within the pump ; all the power is used for positive work, and the pump duty is performed at top efficiency. Operation is successful, even under the most difficult suction conditions, as it will prime " over the hump ", eliminating the air locks caused by inefficient pipe layouts, faulty pipe joints, and similar causes. Other features include automatic " snore " operation for long periods, when the suction-pipe inlet is only partially submerged, and efficient pumping of volatile and inflammable liquids, including petroleum spirits. Furthermore, the open impeller (the only moving part) will

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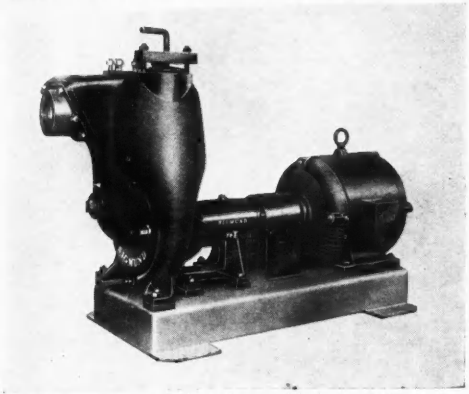
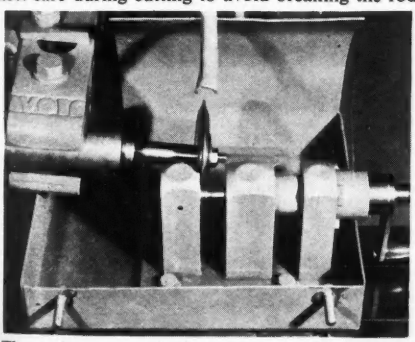
handle solids up to 25% of the suction-inlet diameter, while the shaft is completely protected by a renewable sleeve, and renewable wear-plates are fitted, to ensure low maintenance costs when handling abrasives. In addition, there are no diffusers, ports, or valves.



These pumps are eminently suitable for transfer duties, for circulating, boosting, and water supply for screened sewage, trade-effluent, and waste-liquid disposal, for irrigation, etc. In short, they can be used for all low- and medium-head centrifugal-pump applications, with the decided advantage of automatic self-priming on suction lifts up to 25 ft.

Machining of Valve-Heater Supports from Alumina and Synthetic Sapphine

An interesting workshop technique, recently developed at the Research Laboratories of The General Electric Co. Ltd., enables fine, deep helical grooves to be cut in very hard and brittle materials such as alumina and synthetic sapphire. So far, as many as 28 threads per inch, each 0·035 in. deep and 0·028 in. wide have been cut in rods $\frac{1}{8}$ in. in diameter. This leaves a web of material 0·007 to 0·008 in. thick and a residual solid core rod only 0·055 in. in diameter ; thus, the operation calls for the utmost care during cutting to avoid breaking the rod.



The rods are required as supports for heater filaments in certain special types of valve. Alumina is chosen as the material, as it will stand up to the temperatures required when very pure, and synthetic sapphire, (an extremely pure single-crystal form of alumina) is even better. Both these materials, however, are very hard and brittle, and it has been a problem to machine a suitable support from them. The present technique provides a deep helical groove along the length of the support rod, so that the heating element, consisting of either a single coil or a coiled coil of very fine wire, can be wound onto it. The heater is thus positively and securely located on the support rod, facilitating its assembly in the valve.

The first step in developing the machining technique was to shorten the grinding spindle of a standard tool-post grinder to reduce vibration. The cutting wheel is a 3-in. diameter resin-bonded diamond-loaded wheel running at 6000 rpm. The wheel, which is 0·026 in. thick, is mounted on the spindle, which is set at the desired helix angle, in this case 5°12′. A close-up of the cutting head used is shown in the illustration.

The alumina or sapphire rod is held at one end in a small lathe collet mounted on the end of a lead screw having the desired number of threads per inch. The free end of the ceramic rod is carried in a bush which has a cut-away portion to expose the ceramic. This cut-away portion coincides with the position of the wheel, thus giving support to the ceramic and preventing fracture during cutting. The full depth of the cut is made in one operation, so that side pressure is taken on the bulk material. This is found necessary to prevent chipping of the web. The ceramic rod is advanced by hand, and the time taken to cut a thread of 28 threads per inch, 1 in. long, is about 5 min.

Levelling Machine Mounts

A completely new method of mounting machine tools, providing the answer to a number of problems involved when installing machines, laying out machine shops, or revising a machine line to step up production, is announced by Cementation (Muffelite) Ltd., of London, S.W.1.

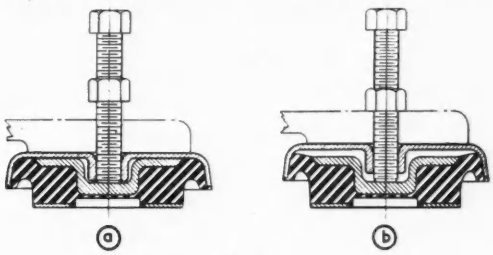


Fig. 1.

The new device, which is known as the Barrymount levelling machine mount, isolates vibration and makes it unnecessary to bolt down or anchor the machine. The outstanding feature, however, is that each mount has its own built-in levelling adjustment. No shimming is required, levelling the machine being a simple operation, speedy and absolutely accurate, so that machines can be installed and set in a matter of minutes. Moreover, as no bolt holes are needed, machines can be located exactly where they are wanted, without having to take account of conduits, pipes, or reinforcement-rods buried in the floor. Other important advantages include the reduction of noise and vibration from heavy or high-speed plant, the minimizing of damage to delicate instrumentation employed to control machines, and the isolation of precision machines from exterior shock and vibration.

It is a simple matter to fit the mount :—The machine foot is lifted and the mount placed underneath. A bolt, with a lock-nut, is passed through the machine foot and screwed down into the central threaded sleeve in the mount, as shown in Fig. 1a, until it bottoms on a metal core embedded in a rubber block, which has a base-plate in contact with the floor. When each foot has been supported, the bolts are screwed down to level the machine, and the lock-nut is tightened (Fig. 1b). Vibrations and shocks are absorbed within the rubber block. The range of mounts covers load ratings of from 70 to 2500 lb. The largest size of mount raises the machine only about $2\frac{1}{2}$ in. above floor level, an important feature with foot-operated machines.

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BEARINGS

Bearings for Marine Geared Turbines.

By A. D. NEWMAN. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle upon Tyne*, February 10, 1956, pp. 205-228, 13 illustrations.)

THE practical design of journal bearings is not, as yet, an exact science. A number of interacting factors is involved in the relation between the dimensions and external conditions and the resulting operating characteristics of a bearing, and in practice the results cannot be closely defined, except by the assistance of empirical rules and for a particular case. In the case of bearings for marine geared turbines, major changes in design are at present coming into practice, and the purpose of this paper is to indicate these changes and, by describing this particular case, to show how the characteristics of such bearings may be estimated.

After considering the prime requirements of bearings for marine geared turbines, i.e., reliability and efficiency, it is shown that the correct choice of length/diameter ratio and clearance ratio is essential in order to attain these requirements, and it is indicated that, for the conditions which occur in most marine turbine and gear bearings, relatively short bearings, with a length/diameter ratio between two-thirds and one-third, and clearance ratios between 0·001 and 0·002 in. per inch diameter, give the best results.

Bearings and shell materials are discussed. The advantages of high-tin whitemetal as a bearing material are shown, and the relative merits of non-ferrous and ferrous shell materials are considered. It is concluded that the best general design is one of thin whitemetal on a steel shell ; the shell may be of normal thickness or it may be of thin-shell type, and the advantages of this design are considered. The requirement of utmost reliability in a marine bearing involves, if possible, the ability for limited operation under a condition of lubricating-oil failure. Thus, to be really reliable, a marine bearing must be capable of withstanding a run-down in speed extending over, say, 5 minutes, without damaging itself or the journal so badly that, on resumption of the oil supply, it cannot again be run up to power. The shortcomings in this respect of present bearings are mentioned, and an improved design which overcomes them is described.

It is concluded that, in general, a marine turbine or gear bearing should be of plain circular type, with two oil inlets. The length/diameter ratio of the bearing should be between $\frac{1}{3}$ and $\frac{2}{3}$, with limits on specific loading. Although the progress of research work is towards a complete analysis of actual bearing performance, the stage has not yet been reached at which a designer, faced with a bearing requirement and operating conditions, can decide conclusively the optimum dimensions and from them obtain the operating data for the bearing. Approximate methods however, give results which correlate well with measured values for normal conditions. It is found with this type of bearing that temperature is a criterion of failure, and it is concluded that the measurement of oil-spill temperature near the load-line should be used. Thin whitemetal on steel backing bearings should be used, and thin shell bearings offer important advantages. The normal safety-strip bearing restricts the choice of shell material and is not entirely reliable ; an improved bearing incorporates a safety lining beneath the whitemetal itself.

FOUNDRY PRACTICE

The " Maprodent " Process of Precision Castings.

By P. LEFRANC. (From *La Technique Moderne, France*, Vol. 47, No. 9, September 1955, pp. 390-392, 6 illustrations.)

IN the lost-wax process the " lost " models are usually made by injection under pressure into rigid metallic moulds. The disadvantage of rigid moulds is that, when complicated shapes are required, the moulds have to be made up of several components assembled together, increasing the cost of the mould considerably and imposing limitations on the dimensions of the casting.

In the " Maprodent " process, the moulds are made of a deformable material which can easily be shaped, as required. The process is particularly useful in the aircraft industry, e.g., in casting small, complicated components of navigating and control instruments. Such components are often made of costly alloys, and the possibility of casting instead of fabricating them reduces waste of material to a minimum. Apart from this factor, the deformable moulds themselves can be made rapidly and cheaply. The dimensional accuracy of the castings is normally of the order of $\pm 0{\cdot}1$ mm per 1 cm, but an accuracy of 0·02 mm per 1 cm is possible.

Research is in progress on deformable materials based on latex, neoprene, and silicone rubber, from which could be made moulds that would be suitable, not only for wax and similar materials but also for certain alloys having a relatively low melting point. Casting with such alloys could then be made directly in the deformable moulds.

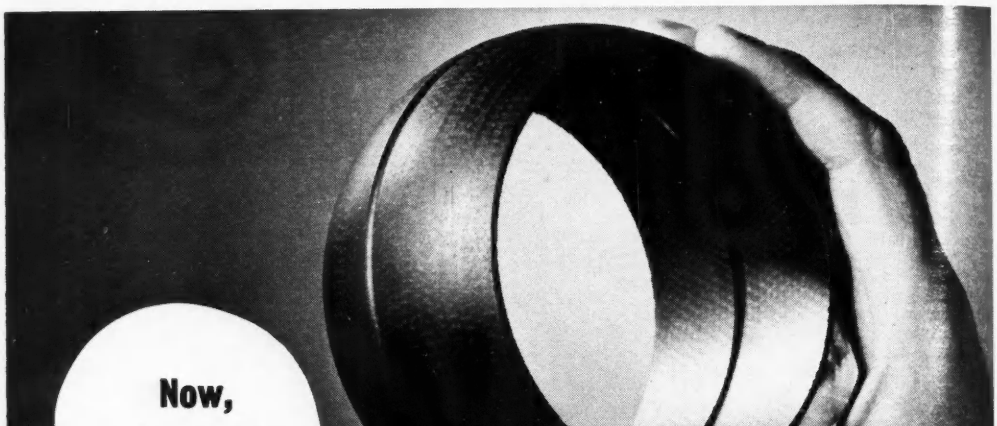
POWDER METALLURGY

The Mechanism of Densification during Sintering of Metallic Particles.

By G. C. KUCZYNSKI. (From *Acta Metallurgica, U.S.A.*, Vol. 4, No. 1, January 1956, pp. 58-61, 1 illustration.)

THE process of sintering, the central process of powder metallurgy, long remained obscure, despite imposing advances made in the last twenty years. However, the results of investigations undertaken during recent years have gradually explained the mechanisms involved. Powder metallurgists usually divide the course of the process of sintering into two largely overlapping stages. The first, during which the mass of heated powder does not densify appreciably but gains in cohesion, is connected with the formation of metallic " necks " between adjacent particles. During the second stage the voids are gradually eliminated, resulting in an increase in the density of the powder compact. It has been well established that both stages are motivated by surface tension. Herring has discussed exhaustively the thermodynamics of this problem.

Two particles in mutual contact form a system which is not in thermodynamic equilibrium, because its total surface energy is not a minimum. If such a system is left for a sufficient period of time, bonding of the two particles will take place, resulting in a decrease of the total surface area. The mechanisms which would effect the bonding are those of surface and volume diffusion, evaporation from convex and condensation on concave surfaces of the system, and plastic or viscous flow. Studies of the initial growth of the " neck " joining an individual sphere of copper or silver and a flat plate of the



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same material on which it was loosely placed, and of wires wound around cylinders, have indicated that, for metals of not too high a vapour pressure, volume diffusion seems to be the predominant mechanism during the early stages of sintering. It is known that it is impossible to obtain full densification of compacts by sintering alone without cold working and resintering because, as soon as the grain boundaries leave the voids, they cease to close.

The fact that the elimination of the pores in a metallic system can be achieved only when the grain boundaries are present suggests two possible mechanisms, i.e., (1) grain-boundary diffusion, and (2) volume diffusion, with grain-boundary sinks (equivalent to the so-called Nabarro-Herring micro-creep). The probability of occurrence of these two mechanisms is discussed in this paper, and it is concluded that the volume-diffusion mechanism is the more probable.

PUMPS

Metallurgical Aspects of the Service Life of Pumps.

By B. DE BORDE. (From *La Houille Blanche*, *France*, Vol. 10, No. 5, October-November 1955, pp. 718-730, 12 illustrations.)

A LARGE number of factors influences the service life of a component moving in a liquid possessing erosive qualities. Apart from the shape and material from which the component is made, its service life is dependent on the agencies working on it. The rate of erosion in a pump is closely connected with maintaining the initial good condition of the surface of the material. Metal can be subjected to abrasion in several ways. The effect of abrasion is said to be " static " when the angle of attack is zero, or " dynamic " when the angle has a certain value, or it can be a combination of both types.

Corrosion can occur independently of, or in conjunction with, abrasion. It is most often due to the electrolytic properties of the liquid causing galvanic action, which attacks some components of the metal, sparing others. Constantly occurring examples of chemical corrosion are those produced by polluted water, harbour water, or by seawater. Severe conditions imposed upon the material (temperature, pressure, friction, etc.) are other complicating factors. Various remedies are suggested for the cases arising in practice.

ROLLING MILLS

Investigation of Different Factors in Hot-Rolling.

By G. WALLQUIST. (From *Jernkontorets Annaler*, *Sweden*, Vol. 139, No. 12, 1955, pp. 923–1030, 119 illustrations.)

IN this paper, it is shown that the calculation of roll pressure, energy consumption, spread, and forward slip in hot-rolling may be based either on a mathematical analysis of the deformation or on coefficient values obtained from direct measurements in rolling mills. The latter method is the only reliable one up to now. After reviewing previous work in the field, an account is then given of the present investigations, both on the deformation process and on the determination of reliable coefficient values necessary for the calculations.

The influence of steel composition, temperature, reduction, and material thickness on roll pressure, energy consumption, spread, and forward slip was studied on sixteen steels. The temperature range investigated was 800 to 1100°C, the reductions 10, 20, 30, and 40%, and the width of material 2·5, 5, 10, and 20 mm.

A description is given of the general methods for calculating roll pressure, energy consumption, spread, and forward slip, using the coefficient values obtained in the investigation. Besides the normal specific roll pressure, the roll-pressure coefficient previously used in cold-rolling calculations is introduced, with the roll pressure stated as the product of the width of material in mm and the roll diameter in mm. The results are summarized in diagrams showing the total and specific roll pressure and forward slip as functions of various rolling factors, as also the influence on these factors exercised by the coefficients of roll pressure, torque-arm, and spread.

The total roll pressure increases, generally speaking, with a rise in carbon content and other alloy contents and with falling temperature, but by different amounts for different qualities of steel ; at times, a rise of alloy content may instead lower the roll pressure, especially at high rolling temperatures. With thin sections an additional rise in pressure is caused by flattening of the rolls and other factors ; this is particularly noticeable at large reductions.

The rolling power is the product of rolling torque and speed. The rolling torque is determined by the product of the specific roll pressures and torque-arm. Since the torque-arm falls with diminishing material thickness, the power diagrams differ from the corresponding diagrams of the total roll pressure, i.e., a high roll pressure is not always accompanied by a high rolling power, and *vice versa*.

The torque-arm coefficient shows values between 0·28 and 0·56, increasing with rising temperature, diminishing reduction, and increasing thickness. The value 0·50 normally used in calculations may thus result in up to near 80% too high rolling power.

The numerical value of the spread coefficient has varied from 0·18 to 1·32. The material thickness and temperature appear to have little effect on the spread.

The forward slip increases with rising reduction and is affected to some extent by material temperature and thickness. The location of equal material and rolling speeds in the area of contact appears to coincide, on the whole, with the corresponding position for the mean total roll pressure parallel with the plane of the main axle.

Some Factors Influencing the Design of Modern Electric Rolling-Mill Drives.

By H. S. BROWN and J. C. EASTON. (From a paper presented at a meeting of *The West of Scotland Iron and Steel Institute*, *Glasgow*, February 17, 1956 ; 33 pages, 24 illustrations.)

ELECTRICAL energy must be placed high on any list of the necessities for the steel industry. A modern steelworks would be unable to function as it does without the electrical equipment which operates so many of its units. This equipment is continually growing in its extent and variety ; its cost as a percentage of the total cost of a new works or mill continues to increase ; the space demanded for it is increasing in many instances, and it is becoming more intricate and complex. In the face of these ever-increasing claims by electrical equipment, many users, whilst recognizing the necessity for much of it, question whether all that is done in the name of advancement is really necessary.

The first part of this paper shows in basic form the reasons behind some of the increases in the extent and complexity of electrical equipment for mill drives, and discusses the general rise in standards, capital costs, running costs, improved mill operation, and new achievements. Typical examples of bloom mills, rod and bar mills, and cold mills are described to illustrate the points discussed.

The paper shows that the increasing complexity of electrical equipment for rolling-mill drives is not merely " science for the sake of science ". In the design of modern equipment all features of mill operation, from the requirements of increased production to the comfort of the operator, have to be considered. The control equipment for a modern main drive can be considered in two sections, i.e., essential equipment in the form of control exciters and magnetic amplifiers, and additional equipment under the heading of " general rise in standards " (e.g., the centralized control boards and alarm panels). The equipment in the second category is con-

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sidered by many to be an added complication and quite unnecessary for the operation of the mill. The alarm scheme and special test features of modern control equipment, however, are essential if fault conditions are to be quickly analysed and production maintained at a high level. This advantage compensates for the increase in capital cost resulting from their inclusion.

STRENGTH OF MATERIALS

An Investigation into the Bending of Angle Beams in the Plastic Range.

By H. N. ABRAMSON, H. A. WILLIAMS, and B. G. WOOLPERT. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 22, No. 12, December 1955, pp. 818–828, 15 illustrations.)

PURE bending in the plastic range when the applied loads are parallel to a principal plane of bending has been studied by a number of investigators. When the loads are not parallel to a principal plane, the complexity of the problem increases very considerably and is further increased when the beam cross-section is not symmetrical with respect to a principal axis.

If plastic action prevails to any large extent, the various parts of an open section must be relatively heavy, and the usual assumptions for shear flow might be questioned. The major obstacle to the solution of the plastic bending problem results, however, from the non-linear relationship between stress and strain. This leads to even more complex relationships between moment and stress and eliminates the use of super-position. Except in special cases, pronounced curvature results in considerable rotation.

It is evident that a rigorous solution of the problem of plastic bending of unsymmetrical beams must be developed from the concepts of pure plasticity, which will give reasonably accurate results. Some attempts in this direction have already been made.

In a previous investigation, by one of the authors, of plastic bending when loads were not parallel to a principal plane, some exploratory tests of angle beams were made. A modification of Cozzone's approach gave a resisting moment at the mid-span which was less than 15% larger than the applied end moment until plastic instability occurred, at which time the percentage difference increased rapidly.

The present investigation is an extension of the previous work. In planning the programme it was decided to test beams of rather long span, in order to accentuate rotation, and to apply the end moments by means of a small eccentric load with a relatively large moment arm. The primary purpose was to determine to what extent a relationship between bending moment at the mid-span and outer fibre stress will agree with the applied end moment if a simplified theoretical approach is used in the analysis. The resisting moment was computed by a modification of Cozzone's graphical method and by an analytical method based on an exponential relationship between stress and strain.

Angle cross-section beams of an aluminium-alloy material were subjected to bending in the plastic range with the plane of loading at various angles to the minor principal axis of the cross-section. The moment was applied by means of an eccentric load with a relatively long moment arm. For a simplified approach, it was found that Cozzone's method of plastic bending analysis and the analysis based on an exponential relationship between stress and strain both gave reasonable correlation between theoretical and experimental bending moments in the plastic range beyond the yield strength. Both methods are approximate, since they assume that the neutral axis does not rotate or translate and the cross-section does not rotate. The exponential method is not valid in the range below the yield strength.

Other factors concerned with the general behaviour of angle beams subjected to plastic bending are also considered

WELDING

Hot-Cracking of Stainless-Steel Weldments.

By P. P. PUZAK, W. R. APBLETT, and W. S. PELLINI. (From *The Welding Journal, U.S.A.*, Vol. 35, No. 1, January 1956, pp. 9s-17s, 17 illustrations.)

THE weldability of stainless steels is a critical factor in the development of high-temperature power plants. In this respect type 347 stainless steel (19/9+Cb) is of particular interest, because of weld-cracking difficulties. Ordinarily, this material is welded without difficulty in the form of thin sheets, in which case cracking problems are either not encountered or are eliminated by means of relatively simple precautions. However, in the welding of heavy forgings or castings of type 347 stainless steels, a considerable number of cracking difficulties has been encountered.

This paper describes the results of laboratory investigations into various heats and forgings of types 347 and 304 (18/8) stainless steels, with the object of establishing the mechanism of weld- and base-metal hot-cracking. As a result of these investigations, it is deduced that hot-cracking of the base metal results from the liquation of fusible segregates located at the boundaries of grains which adjoin the fusion line of the weld proper. The base-metal cracks develop high strain concentrations in the solidifying weld metal and, consequently, the cracks extend into the weld metal. If the weld metal is not susceptible to hot-cracking, by virtue of the presence of primary ferrite, the notch extension mechanism is inoperative. Thus, fusible grain-boundary segregates establish the basic condition for base-metal cracking and for a severe testing of the ability of the weld metal to resist hot-cracking. Large grain size aggravates the segregate problem and therefore the weld-cracking problem.

The presence of weld- or base-metal cracks provides for low-ductility stress-rupture failures during the heat treatment or elevated-temperature service of weldments subjected to yield-point loading. Small cracks which are not visible except at high magnification may serve to initiate low-ductility stress-rupture failures.

Technical and Scientific Training in Russia

(*Concluded from page* 90)

is often incoherent, and the relation to fundamentals is not obvious.

Among metallurgical textbooks, the 600-page "Openhearth Steelmaking" by Trubin and Oiks, as well as Okorokov's "Electric Steel Melting Furnaces" can be quoted as pertinent examples, if statements published in Soviet reviews can be believed. Another 600-page book by Pavlov, a corresponding member of the U.S.S.R. Academy of Science, dealing with the theory of plastic forming of metals, has been described by a group of four reviewers as "completely ignorant". Their detailed analysis of the various bits of nonsense contained in this book ended with the rather pointed remark that it should never have been allowed to get into a student's hand.

Finally, a review which appeared in the April 1955 issue of "Zavodskaya Laboratoria" (Works Laboratory) of a recent book on high-temperature properties and tests contains the following extraordinary (though none the less significant) statement :—

"The author almost completely ignores foreign laboratory experience. On the one hand, this fact indicates the author's desire to bring out as fully as possible the achievements of Soviet investigators, but on the other it leads in many cases to a one-sided and an incomplete treatment of the problem."

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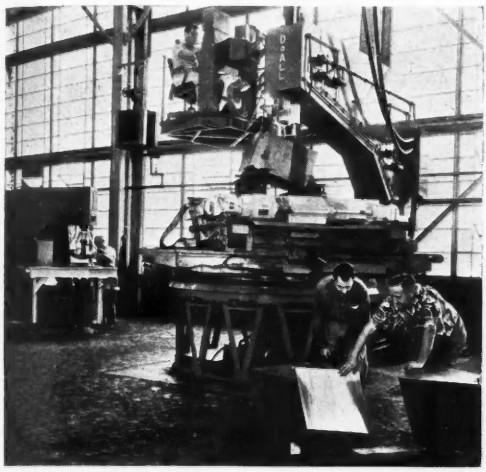
New Materials, Processes, and Equipment

GIANT BANDSAW AND DIE FILER

Stated to be the largest of their type in the world, a bandsaw and die filer have recently been designed and constructed by the DoAll Company, of Des Plaines, Illinois, for production of giant extrusion dies in the Alcoa aluminium plant at Lafayette, Indiana.



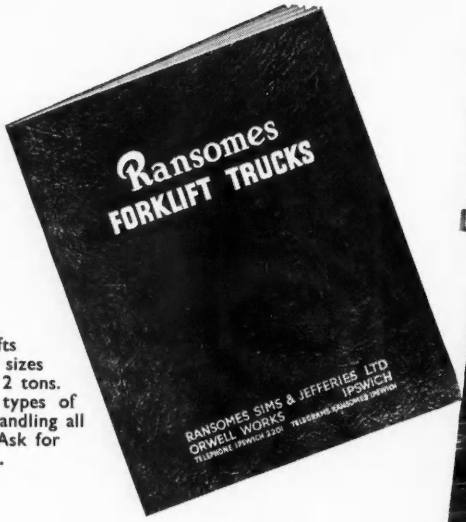
The new bandsaw employs the "contour-sawing" method, in which a narrow saw affords the extreme manoeuvrability and freedom from restriction in cutting geometry necessary for the direct and rapid shaping of materials, permitting the outline of a large extrusion to be sawed directly in the die blank, rapidly and economically. Also produced on this bandsaw are the tremendous jaws required in the stretching machine for seizing the extrusions. The ability of the saw to navigate difficult contours and to cut a narrow path directly along the lay-out line permits two mating jaws to be cut simultaneously from one piece of stock.

Standing nearly 16 ft high and occupying an area of 21 by 17 ft, the saw can handle pieces up to 26 in. in thickness and 52 in. in diameter. However, by reason of its size, it would obviously be impossible for an operator to guide a heavy workpiece with conventional feed devices with anywhere near the accuracy required for the manufacture of a complex extrusion die. In the new saw this problem has been solved by a special electrical and hydraulic control system, under the control of an operator who sits in a control station (illustrated opposite) suspended from the head of the machine and capable of being rotated manually through 90 deg. and swung out over the work surface. By observing the cutting action in close-up through a special periscope, the operator merely steers the work as required by means of a simple control associated with an "electronic brain", which automatically co-ordinates the movements of three vertically stacked, individually motor-driven tables. As will be seen from the illustration, this control is very similar in appearance and arrangement to that used in an aircraft. To move the work into the blade the operator pushes the control-wheel forward, while to retract the work he pulls the wheel back towards him ; to stop all table movements he places the control in a central position. To saw a contour he merely turns the wheel to the right and left, as required.

Because the operator does not touch the work during cutting operations, he is deprived of the normal sense of "feel" for evaluating cutting pressure, cutting rate, etc. This is compensated by means of an indicating control system using strain gauges. Furthermore, automatic safety checks, which stop all table feed motors if cutting and feed forces become excessive, are incorporated. Conveniently at hand to the operator are hydraulically actuated controls for adjusting and maintaining band tension, for ensuring upper saw-guide position, for shifting saw-speed ranges, for varying the speed within a range, and for tilting the three saw-band carrier wheels for tracking the saw. An air jet is provided for removing chips from the lay-out line at the top of the workpiece, and a recirculating coolant system helps to remove chips and to permit a finer finish and longer saw life. The machine, for which saw blades 40 ft in length are required, incorporates a band-speed range of from 50 to 2000 fpm and, because it can accept saw bands from $\frac{3}{32}$ to $1\frac{1}{2}$ in. in width, a high degree of manoeuvrability is possible, permitting the cutting of extremely sharp radii.

Extrusion dies and other parts cut on the bandsaw are finished on the die filer (seen at the left of the first illustration). Standing more than 8 ft in height and occupying 93 sq ft of floor space, this filer has a throat capacity of 28 in. and a work-thickness filing capacity of 19 in. over a 30-in. diameter working area. A unique feature of this machine, necessitated by the otherwise unmanageable weight of the die pieces, is the fact that the work is not directed against the file, but remains stationary on a special, separate work-table. Instead, the file itself is directed against the work, so that the operator must swing the entire jig frame. This, however, can be accomplished with very little effort, as the jig frame proper is suspended above the floor, floating on hinges associated with an intermediate frame or arm which, in turn, is hinged and floating with respect to a heavy support-pedestal anchored to the floor.

The filer employs a variety of file shapes, ranging from 9 to 23 in. in length, and has a filing stroke up to 9 in., with infinitely variable stroke frequency between 50 and 350 strokes per minute. The special work-table can be tilted to 5 deg. in any direction.



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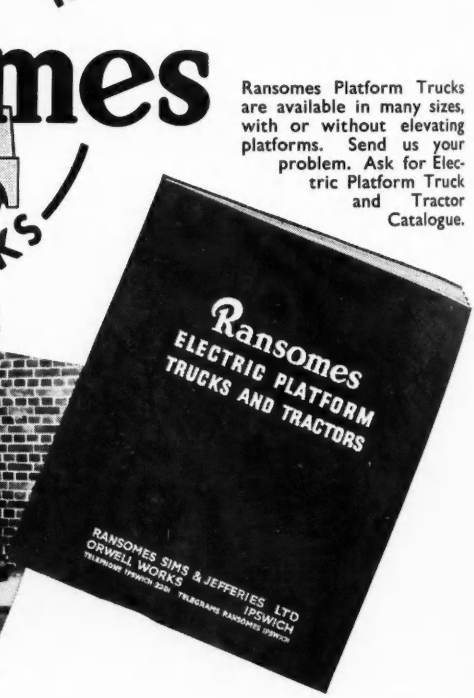

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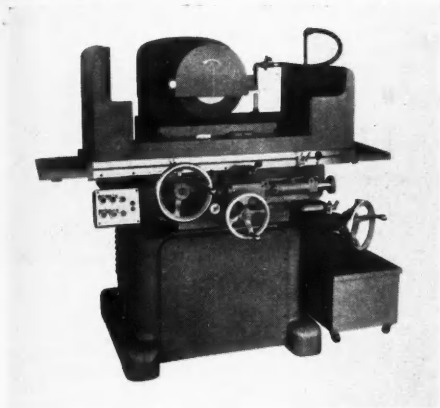
HYDRAULIC-FEED RECIPROCATING-TABLE SURFACE GRINDER

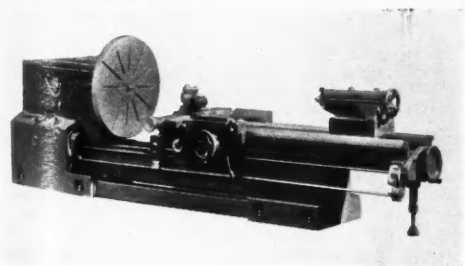
A new horizontal hydraulic-feed reciprocating-table surface grinder, the Covel " 60 ", is announced by the Covel Manufacturing Company of Benton Harbor, Michigan. The new machine is especially suitable for grinding trim, mould and forming dies, forming and blanking dies, plastic mould dies, and die-casting dies.



Power elevation eliminates operator fatigue when the height of the work varies, while a push-button control permits rapid raising or lowering of the wheelhead. A 14-in. diameter grinding wheel, driven by a 3-hp motor, provides ample grinding power for taking heavy cuts. A side range of table speeds (10 to 90 fpm) results in minimum grinding time and reduced costs. For easy maintenance, a closed hydraulic circuit is used, comprising a sealed tank with a pump and motor. All hose connections, including returns, are sealed together with the pump and tank unit, providing a closed circuit which prevents the entry of dirt or of coolant. The machine is provided with vertical ways of generous proportions, cast integral with the base and carefully hand-scraped and aligned with the saddle ways. Automatic lubrication is applied to all bearing surfaces. A three-speed, easily changed spindle is provided, to give the correct peripheral speed of the grinding wheel, even after wear.

EXTENSION-BED GAP LATHE

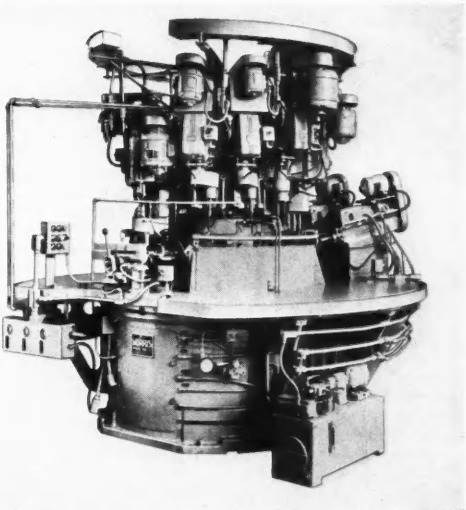
A versatile 20/40-in. extension-bed gap lathe, which swings 24½ in. over the ways and 42 in. through the gap, has been developed by the Nebel Machine Tool Corporation, of Cincinnati, Ohio. All heavy components of the lathe (designated " Imperial "), including the heavy-duty tailstock and the sliding upper bed, are power-operated, requiring no effort on the part of the operator. With a single-speed motor, there are 18 spindle speeds (11 to 666 rpm, or 16 to 1000 rpm). With a 2-speed motor, 36 spindle speeds are available, ranging from 5 to 666 rpm, or 8 to 1000 rpm.



All headstock gears are shaved and hardened, and the entire gear-train is lubricated automatically with an oil spray. Shafts throughout the lathe are mounted on anti-friction bearings, including the headstock spindle, which rolls on three bearings. The quick-change gearbox is completely enclosed and offers a wide selection of 60 feeds and threads through an exclusive selector. Gears are lubricated automatically. The sliding upper bed is of a new design and consists of a combination box girth and diagonal ribbing. Hardened and ground steel carriage ways may be added to the upper bed as extra equipment. The gap-type carriage has 166 sq in. of bearing surface on the bed. The apron is of one-piece double-wall construction, affording double support to shafts.

AUTOMATIC HIGH-SPEED MULTIPLE DRILLING MACHINE

A new high-speed production machine, which drills, burrs, reams, taps, and spot-faces, performing 24 operations on 21 holes on four perpendicular faces and one angular face, has recently been developed by The Morris Machine Tool Company, of Cincinnati, Ohio. The machine may be adapted easily for almost any type of product requiring multiple drilling operations on a mass-production basis. Though it provides specialized machining, it is constructed from standard production units, which permit rapid and easy re-alignment for product-model changes, for completely new models, or for other types of products within the product-size limits of the machine.



The basic unit of the machine, designated 309-S, is a stationary vertical centre column, surrounded by a horizontal removable platen. A hydraulically operated indexing table is mounted on the centre column. Above the table, on the column, and on the horizontal platen are mounted the drill units, which are oil- or air-powered. Each unit has independent feeds and speeds, permitting adjustment of individual units without affecting the machine as a whole. Each drill unit is preset for correct alignment, performing the same operation with each indexing of the machine. All units are controlled simultaneously through an integrated electro-hydraulic control system. The indexing table is fitted with air-powered clamping fixtures. The table indexes through twelve operation stations, where the fixtures are automatically indexed and positioned by cams on the centre column. Thus, the operator has merely to load unfinished pieces and to unload finished pieces.

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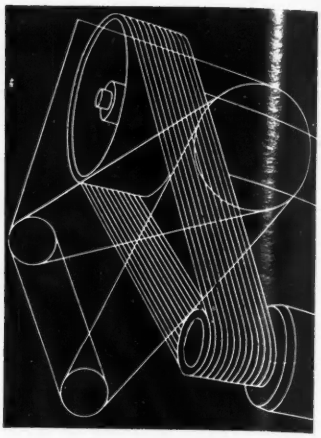

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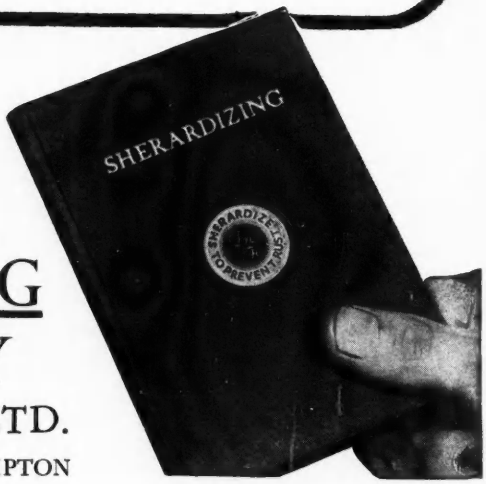

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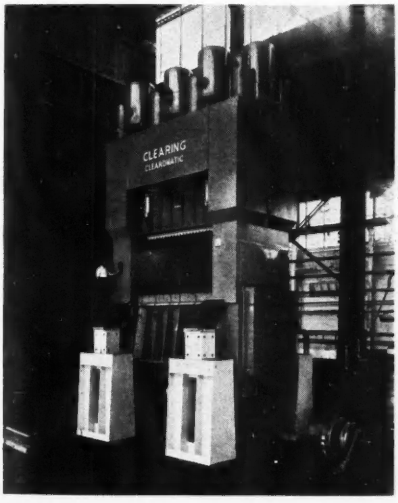
PRESS WITH HIGH-SPEED RETURN STROKE

A new press, with a high-speed return stroke, designated the " Clearomatic ", is announced by the Clearing Machine Corporation, a division of U.S. Industries, Inc., of Chicago, Illinois. The new press is capable of operating automatically at two different speeds during different parts of the stroke. The working portion of the cycle is performed at the slow speed required to prevent tearing of the metal, while the rest of the stroke (75% or more of the total stroke) is performed about three times as quickly, halving the time for one complete cycle.

The heart of the new press is its clutch, which provides a mechanical means of changing the speed of rotation of the drive-shaft while the press is cycling. Changing from one speed to the other is accomplished instantaneously and automatically. At the start of the press stroke, the drive-shaft is driven at high speed by admitting air to the high-speed drive unit located on the flywheel. This engages a clutch-spider assembly, a ring gear, and an internal planetary-gear arrangement, causing it to operate and rotate as a unit at the same speed as the flywheel, and permitting the slide to approach the work at an accelerated speed. At a predetermined point above the work, the high-speed drive unit is disengaged, and the low-speed drive unit is simultaneously engaged, stopping rotation of the clutch-spider unit and the ring gear, while the sun gear continues to rotate with the flywheel. Speed is thus reduced to one-third of its original amount, this reduced speed being that at which the actual drawing of the metal occurs during the press stroke. As soon as the draw has been completed, the high-speed drive unit is once again engaged, and the return stroke is completed at an accelerated speed. At the top of the stroke, both drive units are disengaged, and a brake is applied.



The " Clearomatic " press can be operated in any one of three ways, i.e., at high-speed, low speed, or in combination. In addition, with combination operation, the position of the slide at which speed is changed from high to low and low to high can be varied, as required.

MULTI-WHEELSLIDE SPECIAL-PURPOSE CYLINDRICAL GRINDER

A semi-automatic, special-purpose, multi-wheelslide cylindrical grinding machine, the " CMS-1 ", which can be adapted to a wide range of operations, has recently been developed by the Norton Company, of Worcester, Mass. The principal advantage of the new machine is its ability to plunge-grind multiple diameters simultaneously

on workpieces which, because of their shape, do not lend themselves to grinding on conventional multi-wheel machines.

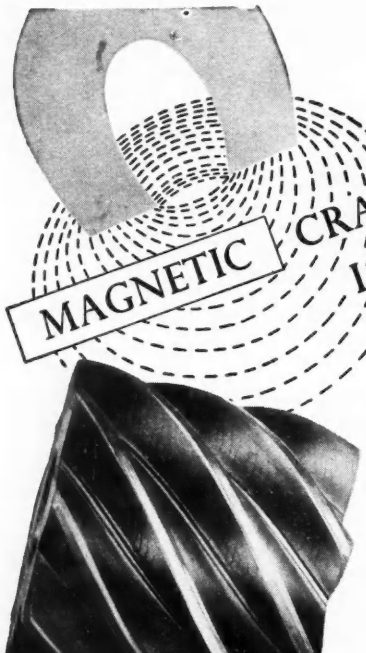
The machine has sturdy wheelslides which are positioned during manufacture for the requirements of a specific job. The wheelslides may be opposed or placed in line, whichever is better suited, while provision is made for slight angular or lateral adjustment of position for set-up purposes. The slides are self-contained with respect to motion and truing, but operate in unison during production. Centrally located " one-lever " control of the automatic grinding cycle and automatic termination of the cycle under electrically timed control greatly simplify operation. Auxiliary independent control of the wheelslides is provided for setting up. Each wheelslide mounts one or more 30-in. diameter grinding wheels, as required. The type of work-holding equipment furnished also depends on the job. Chucking arrangements on a single work-head, or equipment for holding the work on centres, are also available.

A two-speed automatic feed assures availability of optimum conditions for rapid stock removal, workpiece accuracy, and finish. Convenient wheel-feed handwheels with " click-count " indexing mechanisms, which permit feed adjustments in increments of " tenths " without visual attention, facilitate size control in set-up and initial operation. Individual push-button-operated jogging control of wheelslide movement simplifies size control during regular operation. The increments of jogging control are adjustable and all wheelslide feeds occur with fine repetitive accuracy as a result of metal-to-metal contact of the revolving-screw wheel-feed mechanisms. Automatic wheel truing by devices of the wheel-guard type assures efficient performance of the truing function. These devices provide the additional advantages of operating consistently at a predetermined speed and feed, reducing wheel cost per workpiece ground by making possible close, uniform control of the amount of abrasive removed from the wheels.

GENERAL-PURPOSE RELAY

Although measuring only $3\frac{3}{8} \times 1\frac{7}{8} \times 2\frac{1}{2}$ in., what should prove to be true general-purpose relays, with contacts having a continuous rating of 20 A at 250 V a.c., is announced by Besson & Robinson Ltd., of Harlow, Essex. In these relays, a two-pole change-over contact arrangement is used, thereby catering for many requirements, including nearly all single-phase mains switching. In addition, it has been found possible to standardize on a limited number of coils, permitting operation over a wide range of voltages. Coil consumption is low (under 5 vA a.c., and $2\frac{1}{2}$ W d.c.), so that operation over contact thermometers, etc., is possible.

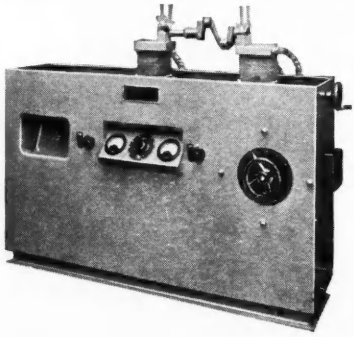
The frame is fully laminated and the patented construction used ensures rapid operation on both altern-



MAGNETIC CRACK DETECTION IS SIMPLE AND SURE

Even when too fine to be detected by any normal inspection method, surface cracks can be discovered immediately with Metrovick magnetic crack detection equipment. Developed primarily for practical tests on components produced in the company's own factories, ranging from large forgings to small pinions, this Metrovick equipment is very simple in operation. Use is made of a special magnetic fluid which, after passage of the magnetising current, enables all cracks to be seen with the naked eye. Most requirements in industry can be met from the standard range of Metrovick crack detectors. Special equipment can, however, be made to order. Please write for full technical details.

No cracks of any sort were visible in this pinion before testing by the Metrovick magnetic method. The whole series of very fine surface cracks shown in the photograph was introduced by heavy grinding after hardening. These emerged clearly when tested with the crack detector. Highly stressed components subjected to grinding, welding, heat treatment, pickling, plating, or similar operations, may be tested as a routine measure with Metrovick equipment.



The Metroflux Type 'S' universal magnetic crack detector is an extremely flexible unit. It is of great value for testing components of large size or awkward shape, and for routine testing of mass-produced components.

METROPOLITAN-VICKERS

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ating and direct current, and inherent silence with alternating current. Other features include screw terminals with " Nyloc " nuts and cable-clamping washers ; replaceable contacts ; stainless-steel armature shafts laid in " Oilite " bearings, to permit rapid operation over prolonged periods ; and tropical finish.

The relay is also available in a weatherproof cast-aluminium box, as illustrated. A $\frac{3}{4}$-in. conduit entry is provided at the top and bottom, and a channel for through-cables is provided behind the delay, which is mounted on a special plate to facilitate its temporary removal when installing the box and the cables.

SELF-POWERED PROPORTIONAL COUNTER CONVERTER

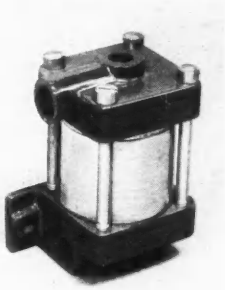
Stated to be the first completely self-powered proportional counter converter to be available commercially, a new instrument, Model PCC-14, introduced by Nuclear Measurements Corporation, of Indianapolis, Indiana, converts any scaler into a proportional counter for measuring alpha and beta activities. The unit has been designed for use in radiochemistry, radiobiology, radiotherapy, health physics, mineral, water and sewage assay, mineral search, and nuclear physics.

The instrument is capable of detecting alpha and beta radiation of all energies. Furthermore, it counts alpha activity alone, even in the presence of high-level beta activity, and beta activity in the presence of alpha. The standard chamber of the unit will take samples in any shape up to a maximum of 2$\frac{1}{4}$ in. diameter × $\frac{7}{16}$ in. thick, while the instrument can readily be adapted to smaller, thinner samples or filter papers or similar samples which can be prepared in cylindrical shape up to 10 in. in length, and approximately 2 in. in diameter.

The yield of the PCC-14 is as high as can be obtained in flat-sample counting. The sensitivity is from 5 to 50 times that of end-window Geiger-Mueller tubes, and does not vary with time, temperature, or humidity. The background count is the lowest available in commercial devices, i.e., approximately one-third that of a Geiger-Mueller tube. Decontamination is quickly accomplished. The unit can be disassembled, decontaminated, and reassembled in less than ten minutes ; alternatively, clean parts may be substituted for contaminated parts in a matter of seconds.

ELECTROMAGNETIC PILOT VALVES

A range of electromagnetic pilot valves of the " glandless " poppet type, employing a new type of actuator of advanced design and performance, is announced by the Baldwin Instrument Co., Ltd., of Dartford, Kent. The development of a highly efficient magnetic circuit, combined with optimum coil design, has resulted in a compact and powerful unit capable of handling fluids at higher pressures and flow rates than have previously been possible. Two models are at present available, both utilizing the same electromagnetic actuator, but fitted with slightly different valve mechanisms. Of these, the unbalanced version (Type V7/11) has a full-bore capacity of $\frac{5}{32}$ in. and will handle compressed air or hydraulic oil at working pressures up to 150 psi. The balanced version (Type V23/11) has a full-bore capacity of $\frac{3}{16}$ in. and will handle the same fluids at pressures up to 100 psi. Both units may also be used for vacuum service.



With both types, electrical consumption is 4 W maximum. There is no " inrush " characteristic, as all models operate on direct current, a simple metal rectifier being supplied as a separate unit for a.c. supplies. Where d.c. supplies are 130 V or higher, a dropping resistor is supplied as a separate unit, so as to avoid the use of very fine winding wires in the coil of the electromagnet. The rating of this magnet is extremely conservative, resulting in a maximum average temperature rise of the coil winding of 35°C, when energized for an indefinite period. The speed of response is very high, and the unit may be operated at frequencies in excess of 600 cps for any desired period. Furthermore, the exclusive use of direct current in the coil results in a complete absence of chatter and overheating. The coil itself is wound on a moulded phenolic bobbin, and is impregnated to withstand the effects of humidity and to improve its heat conductivity. Electrical connection between the coil and the supply lead is made via sprung pins on the bobbin and special terminal sockets contained in the top cover. The unit is totally enclosed.

Both versions are of the 3-way type and may be used either to control small single-acting power cylinders directly, or to operate 3-way or 4-way directional control valves of larger capacity, where power cylinders of larger size and stroke are involved.

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NEWS OF THE MONTH

PERSONAL

Mr. G. C. Abbott has been appointed press officer to Tecalemit Ltd., Plymouth. He will be responsible to **Mr. Gordon G. Goodwin**, marketing manager.

Mr. B. Blair and **Mr. A. A. Chinnery** have been elected executive directors of The Plessey Co. Ltd., Ilford, Essex.

Mr. C. O. Boyse, B.Sc.(Eng.), M.I.C.E., M.I.E.E., Fel.A.I.E.E., director and general manager of British Insulated Callender's Construction Co. Ltd. since 1949, has been elected to the Board of British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1.

Mr. Albert A. Budde has been appointed sales manager of the Components Division of Fairchild Controls Corporation, 225 Park Avenue, Hicksville, N.Y.

Brigadier H. F. Carter, C.B.E., M.C., has been appointed assistant secretary (overseas) of The Agricultural Engineers' Association, 6 Buckingham Gate, London, S.W.1.

Mr. G. F. Clark, B.Sc., has been appointed assistant superintendent of the Steel Products Department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

Mr. W. C. Clegg, formerly purchasing agent at Ferguson Pailin Ltd., has been appointed assistant purchasing agent of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

Sir Walter James Drummond, M.Inst.C.E., M.I.Mech.E., has joined the Board of Sigmund Pumps Ltd., Team Valley, Gateshead. He recently resigned his appointment as deputy chairman of the National Coal Board. Sir Walter has served on the Advisory Council of the Department of Scientific and Industrial Research and on numerous other bodies connected with research and industry.

Mr. C. Eggleston has been appointed manager of the Newspaper Conveyor Department of the Igranic Electric Co. Ltd., Bedford, in succession to **Mr. H. H. Rapley**, who has retired on pension.

Mr. F. Haigh has been appointed commercial manager of the Steel Foundry Department of Edgar Allen & Co. Ltd., Imperial Steel Works, Sheffield 9.

Mr. F. Manley Haines has been appointed production director of PSC Applied Research Ltd., 1450 O'Connor Drive, Toronto, Ontario, Canada, an associate of Hunting Associates Ltd. **Mr. James Speight** has been appointed assistant to Mr. Haines, **Mr. Stein Sunde** has become production manager, **Mr. Oswald A. Schmidt**, assistant production manager, mechanical precision instrumentation, and **Mr. Roy Adams**, assistant production manager, electric and electronic instrumentation. **Mr. Gray S. Willson** has been appointed assistant general manager of Aeromagnetic Surveys Ltd., an associate of PSC.

Mr. A. C. Hall, M.S.M.A.,, has been appointed sales manager of Oliver Pell Control Ltd., Cambridge Row, Burrage Road, London, S.E.18.

Mr. Leonard S. Hermelin has been appointed executive assistant to **Mr. Richard Hodgson**, vice-president of Fairchild Camera and Instrument Corporation, Robbins Lane, Syosset, L.I., New York. **Mr. Russell H. Lasche** has been appointed general manager of the Industrial Camera Division.

Mr. Charles W. Hotchen has been appointed works manager (production) at the factory of Smiths Aircraft Instruments Ltd., Cheltenham.

Mr. Arthur H. Mankin, M.I.R.E., M.A.I.E.E., has joined Induction Motors Corp., 570 Main Street, Westbury, L.I., N.Y., U.S.A., as head of their newly-established dynamotor department.

Mr. J. M. Mitchell, B.Sc., D.I.C., A.M.I.Mech.E., has been appointed chief engineer of the Turbine Department at the Fraser & Chalmers Engineering Works of The General Electric Co. Ltd., at Erith, Kent.

Mr. Stanley Brooks Perry has been elected to the Board of The National Steel Foundry (1914) Ltd., 31 Kingsway, London, W.C.2.

Mr. D. N. Relf, M.B.E., A.M.I.E.E., has been appointed manager of Transformer Contracts, and **Mr. I. A. Ferguson, M.I.E.E.**, manager of the Mining Department, of the British Thomson-Houston Co., Ltd., Rugby.

Mr. G. H. Ross has been appointed manager of the Scottish branch office of Cantie Switches Ltd., whose address is 248 West George Street, Glasgow, C.2.

Mr. B. G. Scott, B.Eng., A.M.I.E.E., has been appointed London sales manager of Lancashire Dynamo & Crypto Ltd., St. Stephen's House, Victoria Embankment, London, S.W.1, in succession to **Mr. V. W. Press**, who is now sales and contracts manager of Lancashire Dynamo Switchgear Ltd., Oxted, Surrey.

Professor Arthur V. Stephens, Professor of Aeronautics at Sydney University since 1940, has been appointed the first holder of the new Chair of Aeronautical Engineering at Queen's University, Belfast.

Mr. Stanley F. Steward, C.B.E., who joined Lancashire Dynamo Holdings Ltd. on 1st January, 1956, as group managing director, has been elected a director and chairman of the Board of Lancashire Dynamo and Crypto Ltd. **Mr. A. W. A. Dick-Cleland, M.I.E.E.**, and **Mr. D. C. Lorkin, F.C.I.S.**, continue as joint managing directors of Lancashire Dynamo & Crypto Ltd.

Mr. G. R. M. Thomson, B.Sc.(Eng.), has been appointed assistant superintendent of the Motor Department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, in succession to **Mr. E. Cowin**, who has been appointed general manager of Metropolitan-Vickers-Beyer, Peacock Ltd., Stockton Works.

Mr. H. R. Walton, B.Sc., sales manager of the Fisher Governor Co. Ltd., Century Works, Lewisham, London, S.E.13, has been elected to the Board.

MR. J. W. WALKER

We regret to announce that Mr. J. W. Walker, a director of Sanderson Brothers & Newbould Ltd., Newhall Road, Sheffield, since 1943, died on 28th February. Mr. Walker joined the company in 1936 and was works director from 1943 to 1954. He was President of the Sheffield section of the Institution of Production Engineers for a number of years and was also a member of The Iron and Steel Institute.

BUSINESS NOTES

Westool Ltd.. St. Helen's Auckland, Co. Durham, announce that extension to their factory premises to be completed this month, will double their production and office area. The range of products manufactured by Westool Ltd. includes Solenoids, Components for Aircraft and Guided Weapons, Fans, Relays, Motors for Aircraft Pumps and Screenwipers and Warner Electric Brakes and Clutches, produced under licence from their American parent company.

The Plessey Co. Ltd., Ilford, Essex, have opened a new factory at Leigh Park Estate, Havant, Hants, to which all Plessey switch production will gradually be transferred. A new type of rotary switch of advanced design is already in production.

Tufnol Limited, Perry Barr, Birmingham 22B, has opened a new branch office at Exchange Buildings, Quayside, Newcastle-on-Tyne 1. Tel. No. : 29693. Mr. J. W. Woolley has been appointed manager of the new office.

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Britain's First Privately Owned Research Reactor. Britain's first privately owned research reactor is to be constructed at the Associated Electrical Industries' Research Establishment at Aldermaston Court in Berkshire. The site for the reactor has been cleared and levelled and design work completed.

The reactor, which is of the water-moderated " swimming pool " type, is simple and versatile, suitable either for research and engineering investigation or for training purposes. It will be used not only by all the companies of the Associated Electrical Industries, but will be available to Universities, Technical Colleges and Research Institutions for undergraduate and post-graduate instruction. A.E.I. will thus be assisting in the training and education of young engineers for the nuclear power programme of this country. Similar reactors are likely to be exported to countries anxious to increase their knowledge of nuclear physics.

The reactor, known as " Merlin " (Medium Energy Research Light-Water-Moderated Industrial Nuclear Reactor) has been designed and will be constructed (subject to local planning permission) by the A.E.I./John Thompson Nuclear Energy Group. The uranium fuel is being provided by the United Kingdom Atomic Energy Authority, with whom the group has always collaborated.

The Associated Electrical Industries/John Thompson organization, very shortly to be formed into a company to be known as The A.E.I./John Thompson Nuclear Energy Company, has as its main purpose, the development and construction of power reactors and complete power stations. The new company will gain useful practical experience in constructing this reactor which, although small, represents a new departure in the development of atomic energy.

So far in Great Britain research and development of reactors has, for the most part, been in the hands of the State. Research has been carried out at the Atomic Energy Research Establishment at Harwell and the production of power reactors at Windscale and Calder Hall. The White Paper issued last April outlined the pattern of future development by industry of power reactors for the Central Electricity Authority. Associated Electrical Industries in collaboration with John Thompson are preparing designs for such power reactors.

The new reactor is the first to be built and operated outside the authority and for use by industry.

More than a year ago industry was asked to consider designs for medium powered research reactors suitable for industrial and academic research. Of a type suitable for export, they could make use of the uranium fuel offered by President Eisenhower to the United Nations on 15th November, 1954, and by the British Government to the United Nations on 16th November, 1954. Associated Electrical Industries, together with the John Thompson Company of Wolverhampton, agreed to do this and designs of a water-moderated research reactor were prepared in time for the Geneva Conference on Atomic Energy last year. Besides serving as a prototype, the new reactor will provide a powerful tool for A.E.U.'s research scientists and engineers to make their contribution to new inventions and ideas on nuclear power.

The basic research undertaken at the A.E.I. Establishment at Aldermaston Court, under the direction of Dr. T. E. Allibone, F.R.S., is by no means confined to nuclear or metallurgical problems. Its activities are complementary to the work carried out in the research laboratories of British Thomson-Houston, Metropolitan-Vickers, Sunvic, Siemens Brothers and Ediswan, and indeed, of all the companies within A.E.I.

The basic nuclear physics research which started at Aldermaston Court nine years ago involves the use of two Van de Graaff accelerators which provide proton and deutron beams used to irradiate various light nuclei. By examining emitted particles and gamma rays from the induced nuclear reactions, important data is obtained on the fundamental properties of the nuclei and the forces which bind them together.

A reactor group, established in order to provide within A.E.I. a research team capable of investigating the physics and engineering problems of present and future reactor systems, is based on personnel trained about the accelerators at Aldermaston. This group has been responsible to A.E.I./Thompson for the design of the core, shield and control system of the new research reactor.

An accelerator group is also playing an important part in the research programme. One of the accelerators operating at 4,000,000 volts is being used to produce high speed hydrogen atoms for disintegration experiments.

" Merlin ", as the new reactor is called, will enable scientists and engineers within A.E.I. to study developments closely linked with power reactors, as well as problems in chemistry, physics and metallurgy under the influence of neutron bombardment.

The Southern California Edison Company will be the first utility in California to produce electricity from atomic energy.

The Atomic Energy Commission has authorized Atomics International, a division of North American Aviation, Inc., and the Edison Company to negotiate a contract in connection with the Atomics International experimental reactor near Santa Susana. With this authorization the Edison Company can proceed with its plans for installation and operation of generating equipment there which will produce electrical energy from the heat developed by the reactor.

James F. Davenport, Edison vice-president and general manager, said that the company will gladly share the information and experience it derives from building and operating the station with others co-operating with the Atomic Energy Commission and North American Aviation, Inc. Representatives of other public and privately-owned utilities will be allowed access to the station to obtain information on engineering features and data and to observe operating and maintenance phases of the project.

Mr. Davenport said that the company probably will be feeding electricity from this pioneer nuclear electric plant into its lines for commercial use in the Santa Susana area some time during the summer of 1956. It will take Edison engineers about six months to install the generating facilities and have them ready for trial operation. The company already has available substation and transmission facilities at the site.

The Edison nuclear electric plant will be operated as a research and development project. It will supply only a fraction of 1 per cent. of the company's total system requirements.

Imperial Chemical Industries Ltd. announce a reduction in the price of their raw titanium to about 21*s.* (below $3) per lb. This compares with the current price of $3.45 in the U.S.A.—at present the largest producer and user of raw titanium. The reduction means that I.C.I. is producing, by its new sodium process, titanium of the highest purity at what is now the lowest price in the world.

Only ten or twelve companies have so far entered the field of raw titanium production on a large scale, and there has been keen competition between them to improve extraction techniques so as to cheapen their product, which is the raw material for the producers of wrought titanium products for industry. In consequence, from a price of 5 dollars a pound at the beginning of 1954, the price of first-grade titanium has dropped in five successive reductions to $3·45.

I.C.I.'s titanium has important advantages in its physical form. Instead of the coke-like " sponge " of the conventional Kroll process, the titanium is in the form of small granules which can be pelleted with alloying materials into a form ideal for the difficult process of melting.

Titanium was first discovered in 1790, but it was not until after 1925, when the first sample of high-purity metal was produced, that the full potential of titanium began to be realized. When free from harmful impurities, titanium can be alloyed to possess the strength of stainless steel, and it is little more than half the weight. It has the highest strength-to-weight ratio of any commercial metal. and it has outstanding resistance to corrosion. These properties make it immediately attractive for aircraft construction and for jet-engine components, and much wider fields of use are opening up as the cost is reduced. The availability of titanium at a relatively low price is therefore likely to have industrial importance by no means confined to the aircraft industry.

The Portable Electric Tool Manufacturers' Association announce that the Annual Conference of European electric tool manufacturers—being held for the first time in Britain—opens in London on 27th June.

Delegates from most European countries, including France, Italy, Sweden, Holland, Switzerland and West Germany are expected. Discussions, in the main, will cover technical matters of mutual interest, from which industrial users everywhere will ultimately benefit.

The British manufacturers sponsoring the Conference are Consolidated Pneumatic Tool Co. Ltd., Desoutter Bros. Ltd., Kango Electric Hammers Ltd., and Wolf Electric Tools Ltd.

So as to enable the Continental delegates also to keep abreast of the latest British machine tool developments, the Conference has been timed to coincide with the International Machine Tool Exhibition at Olympia.

Quality Control Society Convention. More than eighty speakers from the United States, Europe and Canada will be addressing the 10th Annual Convention of the American Society for Quality Control, to be held on 6th, 7th and 8th June, 1956, in Montreal's Palais du Commerce, which offers complete convention facilities. Over 2,000 delegates from the United States and Canada are expected to attend.

Present plans include some forty to fifty exhibits, showing recent developments in gauges, calculators and other devices. Many exhibits will show applications and new techniques.

Plant tours through leading Montreal industries have been arranged to provide examples of Canadian applications of statistical quality control techniques. Copies of all talks given during the convention will be available in bound volumes. A book booth will exhibit the most up-to-date books available on quality control and industrial statistics.

The Montreal Convention Committee is under the chairmanship of B. H. Lloyd, Leetham Simpson and Elliott Limited. Richard H. Peck, Steel Company of Canada, is in charge of exhibits at the Palais du Commerce. The other members of the Montreal Host Committee are : Vice-Chairmen: J. B. Leadbetter, Bell Telephone Company of Canada ; Brant Bonner, University of Western Ontario ; A. P. Deacon, Quality Control Consultant, Brantford, Ontario ; Accounting : Claude I. Taylor, Trans-Canada Air Lines ; Arrangements : Lloyd A. Wedge, Trans-Canada Air Lines ; Roger Lessard, Ecole Polytechnique ; Programme : J. B. Pringle, Bell Telephone Company of Canada ; Publicity : R. Vance Ward, Canadian Industries Limited; Reception : P. G. Macklem, Northern Electric Company and Registration : E. N. Beckett, Northern Electric Company Limited.

SIMA House Display. The output of the British instrument industry is valued at £60 million a year, of which £15 million are exported, said Sir Norman Kipping, J.P., director-general of the Federation of British Industries, when he opened the display at SIMA House on 9th February. He stressed the importance of instruments in all branches of industry and welcomed the enterprise of the Scientific Instrument Manufacturers' Association in establishing a display of instruments at their headquarters at 20 Queen Anne Street, London, W.1.

Sir Norman said that the fact that of the 50,000 workers in the instrument industry 2500 are engaged on research and development work augurs well for the future.

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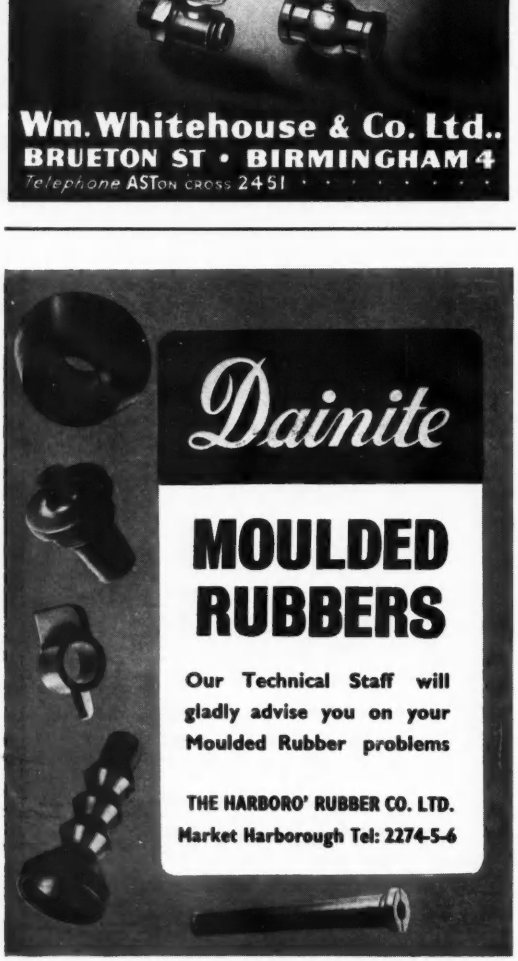

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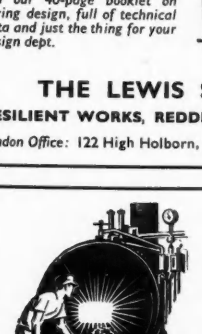

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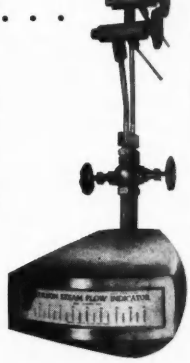

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The object of the display is to provide a centre where overseas visitors can see a representative selection of instruments made by over 140 member firms in all parts of the country. An extensive catalogue library is being built up to aid enquiries. The centre will also serve as a common meeting ground for makers and users of instruments in this country.

Since it is impossible to give space to all members at the same time, a rota system has been worked out which will not only give every member a chance to exhibit, but will also ensure that the character of the display will change constantly. It is hoped that this will maintain interest in the exhibition and foster its use by visitors.

British Insulated Callender's Cables Ltd. are now installing a 2 million volt particle accelerator at their Research Laboratories at 38 Wood Lane, London W.12. This is one of the first particle accelerators to be installed in the United Kingdom for purely industrial researches.

The accelerator is of the Van de Graaff type, housed within a pressure container operating at about 300 lb/square inch. It is a universal apparatus which can be adapted to supply high energy beams of electrons, positive ions, neutrons or gamma rays.

The installation will be used for general research into the effects of high energy irradiation on materials used in cable and capacitor manufacture. In particular, it will be employed for continuing the researches on the effect of irradiation on polyethylene, on which the Company has carried out considerable work during the last few years.

Follsain-Wycliffe Foundries Ltd., Lutterworth, near Rugby, have taken over from International Pulverisers Ltd. the manufacturing and selling rights of the " Pulmac " range of mills, part of which they have been manufacturing on their behalf for some years.

Foundry Equipment Ltd., Linslade Works, Leighton Buzzard, Bedfordshire, have taken over the manufacture, sale and servicing of all magnetic moulding machines hitherto manufactured by British Insulated Callender's Cables Ltd. Mr. H. J. Thompson is sales manager of Foundry Equipment Ltd.

The Caterpillar Tractor Co. Ltd., 32 Sloan Street, London, S.W.1, have decided to build a new factory at Tannochside, Lanarkshire, Scotland, designed for the manufacture of 1500 tractors a year. Production is expected to start in 1958.

Index-Verkaufs-Ges.m.b.H., Stuttgart, Germany, have transferred the sales and service of their automatic screw machines and automatic chucking machines to Leo C. Steinle Ltd., 93 Albert Embankment, London, S.E.11. Tel. No. : RELiance 3981–7.

The Eleventh Annual Electronics Exhibition, organised by the Northern Division of The Institution of Electronics, will be held from 12th to 18th July, at the College of Technology, Manchester. The Exhibition will incorporate a Scientific and Industrial Research Section and a Manufacturers' Section. Approximately 50 lectures and 16 film shows on electronic topics are contemplated. Free tickets can be obtained from the honorary secretary of the Exhibition, Mr. W. Birtwistle, 78 Shaw Road, Thornham, Rochdale, Lancashire.

The Empire and Commonwealth Year Book 1956, edited by R. S. Russell and published by Newman Neame Ltd., 50 Fitzroy Street, London, W.1, has just been published. In 530 pages, the book contains a wealth of statistical and other essential information about more than 80 countries of the Commonwealth and Empire. It provides a concise reference book of utmost value to all interested in trade and cultural relations with the Commonwealth countries. Price : 45*s*.

Bibliography on Mechanism. P. Grodzinski, Dr.Ing., A.M.I.Mech.E., of 41 Tudor Close, Belsize Avenue, London, N.W.3, has built up during the past ten years a large collection of published material on mechanism and related subjects. He has now decided to make this material available to technical colleges as well as to designers and engineers in industry.

Under the title " Mechanism ", the first issue of this international bibliography has now been issued. Sample copies can be obtained free of charge on application to Dr. Grodzinski at the above address.

Fibreglass Ltd., St. Helens, Lancashire, announce the acquisition of additional factory premises at Valley Road, Birkenhead.

Mr. Alan Hudson Davies, managing director of Fibreglass Ltd., said that the choice was influenced by the existence of a well-built and spacious factory suitable for specialized production requirements and its proximity to the Research and Development Unit and the headquarters of the company.

Provision is being made at the new works for the production of certain Fibreglass wool, tissue and continuous filament materials, and the first manufacturing unit will be installed by the end of this year.

Honeywell-Brown Ltd., 1 Wadsworth Road, Perivale, Middlesex, announce the formation of a Micro Switch Division, to manufacture the latest types of precision snap action switches, developed in the U.S.A. by the Minneapolis Honeywell Regulator Company.

Acheson Colloids Ltd., 18 Pall Mall, London, S.W.1, announce the formation of a new company, Acheson Colloiden N.V. with a plant in Scheemda (Groningen), Holland, which will be in production by the end of this year. Mr. Howard A. Acheson, President of Acheson Industries, Inc., has also announced the building of a new Acheson factory during the current year.

The First British Commonwealth Welding Conference, organized by The Institute of Welding, will be held in London and Saltburn-by-Sea, Yorkshire, from 17th to 29th June, 1957.

The Organizing Committee invites offers of Papers for presentation at the Conference on the present position in the U.K. of welding in Boilers and Power Station Plant ; The Oil Industry ; Bridges and Structures ; Shipbuilding ; and The Nuclear Energy Programme.

Full information can be obtained from the Secretary of The Institute of Welding, 2 Buckingham Palace Gardens, London, S.W.1.

Associated Electrical Industries Ltd. and **E. K. Cole Ltd.** announce that their negotiations for the formation of a new Australian company in connection with television and radio developments have reached an advanced stage. An authorised capital of £A.1,000,000 is proposed for the new company.

Discussions are proceeding with Australian Electrical Industries Pty. Ltd. for distribution and servicing the products of the new company.

Technical Ceramics Ltd., a new company recently formed in the Towcester area, Northants, is introducing materials for application to ultrasonic techniques. In addition, development and exploitation of new techniques in the ultrasonics fields is contemplated.

The Sonotone Corporation, Elmsford, N.Y., and Gulton Industries, Inc., Metuchen, N.J., are associated with the new company, whose Board consists of Mr. W. F. Cross, Mr. P. W. Faulkner, Mr. K. L. Spector and Mr. F. Beacroft.

The Physical Society's 1956 Exhibition will be held from 14th to 17th May in the Old and New Halls of the Royal Horticultural Society, Westminster.

The policy of the Society, to show as much as possible of that which is novel and new, has not been changed, and it is anticipated that the standard of the Exhibition in 1956 will be higher than ever before. In addition a greater number of universities, colleges and research organizations have agreed to take part, thus increasing the proportion of purely research exhibits. As is usual, exhibits will show the trend of instrumentation in industry, research, and teaching for the next twelve months. Prominently displayed will be much equipment concerned with the peaceful use of atomic energy. Other exhibits include theoretical and practical work showing developments and application of computers; in particular their application to automatic control in industry.

One hundred and thirty-one exhibitors will show the ever increasing contribution that British Science is making to national and international prosperity.

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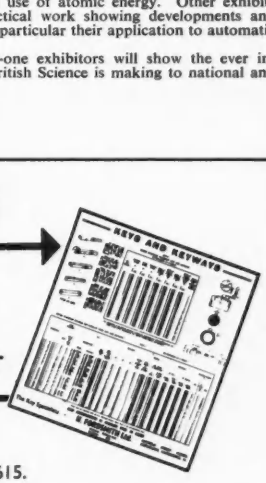

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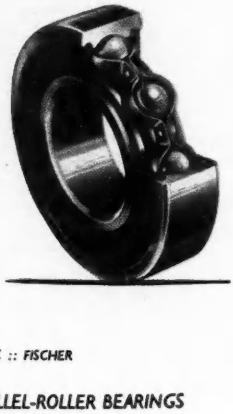

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Classified Advertisements

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

DESIGN AND DEVELOPMENT

The Wolverhampton branch of a world-wide industrial organization offers permanent positions with excellent prospects of promotion for both senior and junior staff as:

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Although salaries will vary according to qualifications and experience, they will range up to approximately £1,300 for technicians, £950 for design draughtsmen and £800 for detail draughtsmen. Excellent opportunities exist for candidates possessing a particularly high potential to obtain higher salaries than those quoted.

Excellent conditions of employment include a Pension Scheme, a 5-day 40-hour week and more than adequate canteen and sports facilities.

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Following the recent transfer of the Aircraft Wiring Engineering Unit from Ilford, the Plessey Company Limited offers excellent opportunities for experienced Engineering Staff to be located at their Swindon Works. Schemes of Housing Assistance or Industrial Housing preference will be extended to successful applicants. These are all permanent progressive posts with a rapidly developing organization.

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Three Senior Draughtsmen and two Detail Draughtsmen are also required for duty in support of the foregoing personnel. Promotion to Engineering grades will be offered in the future to Draughtsmen showing the necessary aptitude.

Write, in the first instance, in confidence, giving details of training. education and experience, to Mr. R. Keir Watson, General Manager, The Plessey Company Limited, Kembrey Street, Swindon, Wiltshire.

LIAISON ENGINEERS

Power Auxiliaries, an Anglo-American Company, invites applications from liaison engineers to join the Company which has its manufacturing centre at Swindon, Wilts.

Two groups are required, one to cover the aircraft industry and the other, diesel, nuclear and marine engineering. The Company has access to latest developments within these industries in both countries and is now commencing to plan customer/liaison service for a new flexible metallic hose.

As one of the Plessey Group of Companies, it is envisaged that considerable expansion will ultimately take place, as the product is new to this country and has innumerable applications in the industries quoted.

Engineers applying should be familiar with the Industries quoted above and preferably have good contacts at senior design level. Write as fully as possible quoting experience, etc., to Mr. R. Keir Watson, Director, Power Auxiliaries Ltd., Kembrey Street, Swindon, Wiltshire.

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Graduate Engineer required for development work on magnetic and electronic amplifiers for servo systems in Industrial Control Applications, including Mining and Heavy Industry.

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Apply for application form, quoting reference " S.4.", to :—
Personnel Manager,
Metropolitan-Vickers Electrical Co. Ltd.,
Trafford Park, Manchester 17.

FORGING HAMMERS FOR SALE

2 RYDER 5-Slide Forging Hammers for sale. Capacity round and square bars up to 1¾ in., tubes up to 3 in. diameter. Weight about 36 cwt. each. Similar 4-slide Machine also available. Photos, F. J. Edwards Ltd., 41 Water Street, Birmingham 3. CENtral 7606.

DRAWBENCHES FOR SALE

DOUBLE CHAIN DRAWBENCH by Sir James Farmer Norton for sale. Motorized with 3 speeds. 400/440/3/50. 5 link chain of 40/45 tons tensile. Plug drawing about 19 ft. long, 2 sets air operated plug pushing gear. F. J. Edwards Ltd., 359 Euston Road, London, N.W.1.

BEARINGS

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CONTRACTS

Pirelli-General Cable Works Ltd., an associated company of The General Electric Co. Ltd. of England, has received a repeat order through its Canadian affiliate, The British General Electric Co. (Canadian) Ltd., for the manufacture and installation of three further lengths of 301 kV oil-filled power cable, total length approximately 6,000 feet of cable, from the Aluminium Company of Canada Limited.

The cable, believed to be the most highly loaded on the North American continent, is required for the Kemano-Kitimat project for which Pirelli-General Cable Works in 1954 supplied and installed a complete 3 phase circuit of 3 single-core cables. The new circuit will deal with the additional power being brought into service from the subterranean power-house at Kemano. As in the previous installation, the cables will run through a 670 yard long tunnel to the terminal of the overhead line which delivers power to the electrolytic refining plant at Kitimat, fifty miles away.

British Insulated Callender's Cables Limited announce the award of a £365,000 contract from the Ministry of Transport and Works of the Government of Ceylon. The contract is for the supply and installation of fifty-five miles of 33 kV, 11 kV and auxiliary pilot cables.

The 33 kV cable with associated pilots will feed various substations from the receiving station at Kolonnawa, Colombo, whilst the 11 kV cable will reinforce and extend the existing system to meet present and future loads.

The contract calls for 26½ miles of 3-core, 0·3 sq in. 33 kV solid screened type cable, lead-alloy sheathed, steel tape armoured and served overall, together with 6 miles of 11 kV belted type cable, and 22¾ miles of lead-sheathed pilot cable.

The first section, comprising 7.4 miles of 33 kV and 3·7 miles of pilot cable, is due to be completed by August of this year.

The Capricornia Regional Electricity Board, Queensland, has ordered another 15,000 kW. Brush-Ljungstrom turbo alternator set, manufactured by **Brush Electrical Engineering Co. Ltd.,** Loughborough, for the Rockhampton power station. The order was placed through Brush Electrical (Australia) Pty. Ltd., Sydney.

This brings the total number of Brush-Ljungstrom 15,000 kW. sets recently ordered by the State Electricity Commission of Queensland, to four. The other three were for the regional electricity boards of Townsville, Wide Bay, and a previous set for Capricornia.

The Townsville set has been installed and commissioned. The other two are in course of erection. All four sets are designed for generating at 11,000 volts with steam conditions at 400 psi and 750°F.

Two important switchgear orders have recently been secured by the **British Thomson-Houston Company**; the switchgear will be made at the BTH Willesden works, where the manufacture of switchgear has been concentrated for more than forty years.

(i) One of these orders, which is to the value of £230,000, comprises 3·3 kV, 150 MVA air-break switchgear and is for the Capenhurst works of the United Kingdom Atomic Energy Authority. It is a repeat of an earlier order valued at £213,000 now nearing completion.

(ii) The second switchgear order, valued at £275,000, has been secured from the Southern Division of the Central Electricity Authority. It is for 66 kV, 2500 MVA switchgear at Iver Substation where the 275 kV Super Grid feeds into the 66 kV London Grid. The order includes fifteen type " OW.407 " Shuntarc resistance switched oil circuit breakers which have been chosen due to their special suitability for switching the 66 kV cable system.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Steel plate, sheets and strip. B.S. 1449 : 1956 supersedes the first edition which was published in 1948 to replace B.S. 5006, B.S. 5007, B.S. 725 and B.S. 847. It thus provides a comprehensive schedule of steels in the form of plate, sheet and strip for use in the automobile and general engineering industries in the same way as was done for steel bars, billets and forgings by the issue of B.S. 970.

The new edition, which is associated with the recently issued revision of B.S. 970, brings the requirements up to date. At the same time it has been designed to cover the requirements of the Services as far as they are compatible with those of Industry in general.

A notable addition is provision for non-strain-age embrittlement quality of certain low carbon materials. En60 and En61, which cover 17 and 20% chromium rust-resisting material, have also been added. Price 6s.

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BOOKS RECEIVED

Kempe's Engineers Year-Book, 1956. (61st edition). Edited by C. E. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. 2786 pp. Publishers : Kempe's Engineers Year-Book, 28 Essex Street, Strand, London, W.C.2. Price (two volumes in case) : 75/- (postage 2/6).

Each year every chapter of this comprehensive, up-to-date, and authoritative treatise, covering practically every branch of engineering, receives the close attention of an eminent authority, to ensure that its contents keep abreast of the latest developments. Changes in the 1956 edition include an entirely new chapter on " Foundations and Earthwork " ; the rewriting of the chapters on " Aerodynamics " and " Aircraft Propulsion " ; additions to the chapters on " Electrical Engineering ", " Electronic Engineering ", " Gas and Gas Engineering ", " Steam Engineering ", " Steam Turbines ", " Mining Engineering ", " Explosives ", " Industrial Safety and Protection ", " Concrete and Reinforced Concrete ", and " Depreciation " ; and many revisions in other chapters.

As always, this useful reference work includes a comprehensive index, while many chapters have a short bibliography detailing the standard works on the subject concerned.

Factory Electrification. By F. T. Bartho, A.I.E.E., M. Inst.W., and C. H. Pike, A.M.I.E.E. 408 pp., 174 illustrations. Publishers: MacDonald & Co. (Publishers) Ltd., 16 Maddox Street, London, W.1. Price : 35/-.

As the authors state in their preface, experience shows that in practice the problems arising in factory electrifications are concerned with the correct selection, operation, and maintenance of the electrical distribution equipment and the motors for the factory machines. Effective operation of factory machines depends, amongst other factors, on correct motor selection, and this is one of the subjects discussed in detail in this book, with emphasis on the economic aspects of motor selection and operation. Furthermore, since problems of factory electrification can be resolved only by understanding the principles involved and knowing by the range of equipment available to meet particular requirements, this book discusses factory electrification in terms of principles and of the capabilities and limitations of the various forms of equipment, with descriptions of representative types.

For these reasons, this book should be of inestimable value to executive engineers, to those concerned with the installation and maintenance of electrical plant, and to all interested in factory electrification in general. The subject is treated in an essentially practical manner, easily intelligible to all who are familiar with the elements and practice of electrical engineering. General requirements in installation, distribution, cable, and wiring systems are dealt with, together with details of the various types of a.c. and d.c. motors and their control gears.

Handbook of Barrel Finishing. By Ralph Enyedy. 260 pp., 242 illustrations. Publishers : Reinhold Publishing Corporation, New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price : 60/-

Here, for the first time in book form, are the complete details of this precise, economical method of finishing metal and plastic parts. Every phase of barrel finishing, from cleaning and deslugging to colouring, polishing, and burnishing, is covered in step-by-step sequence. More than 150 complete specification sheets provide all the information necessary for finishing a large variety of parts. The latest developments in equipment, finishing compounds, and methods are described in full detail. Much of the information on such operations as preparation of metals for sealing to glass, deburring of screw machine parts, and multi-barrel processing has never before appeared in print.

This book will prove of the utmost interest and value to anyone concerned with parts-finishing. Industrial and methods engineers will learn the cost-saving advantages of barrel-finishing methods over tedious, expensive hand-finishing operations, while finishing-department supervisors will find the book a quick reference guide to the equipment, materials, and techniques of barrel-finishing. At the same time, suppliers of tumbling equipment, chemicals, abrasives, and other raw materials will learn how their products are used, and will gain many ideas for further product research and development.

Electric Motors and Controls. 300 pp., 114 illustrations. Published by the British Electrical Development Association, 2 Savoy Hill, London, W.C.2. Price: 8/6 (postage 6d).

The electric motor, correcly used, is one of the greatest known aids to productivity, and its unique property of providing flexible power under exact control gives it an assured place in all industries. It does not necessarily follow, however, that electric motors are always used to full advantage from the standpoint of maximum productivity. It is the purpose, then, of this interesting and informative book (No. 3 in the " Electricity and Productivity Series " published by the British Electrical Development Association) to review the applications of electric power in a wide range of industries and to point the way to the most efficient use of the electric motor by describing, in clear language, the various types of electric motors and explaining why a particular type is chosen for a specific job when maximum productivity, combined with economy, is required.

The electric motor is naturally adapted to automatic control, and such associated control gear is inherently reliable, accurate, and speedy in operation. A well-designed combination of motors and control gear will always make for considerable economy and increase in productivity, and the types, functions, and applications of control gear are also satisfactorily covered in this useful volume.

Bearing Lubrication Analysis. By R. R. Slaymaker. 122 pp., 59 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price : 40/-

Written for the machine designer rather than the lubrication specialist, this book covers the general principles of lubrication analysis in bearing design. Its treatment, though concise, is broad enough to provide the insight needed to design actual bearings for simple cases and to handle the important preliminary planning for more complex applications.

The treatment stresses sleeve bearings, the most common type of bearing found in machines. Its discussion is fully illustrated with case studies and numerical examples. There is a useful outline of hydrodynamic theory as a guide to the design of bearings lubricated from an external source, a discussion of the characteristics of various bearing materials, and an analysis of oilless bearings.

Throughout the book, the vital topic of oil viscosity is emphasized. The author, who is Professor of machine design at the Case Institute of Technology, presents a practical method of predicting temperature rise and oil viscosity in one operation, eliminating trial-and-error solutions. The method, which is illustrated by actual case reports, is drawn from the author's award-winning ASME paper and has never before appeared in book form.

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1. Centre Lathe. A leaflet describes and illustrates a new 10½-in. centre lathe with many interesting features, including rapid selection of spindle speed with clear indication of the desired speed, and a totally enclosed, automatically lubricated quick-change feed gearbox with provision for metric, module, diametral, and fractional pitch thread cutting, without recourse to a multiplicity of gear wheels. The lathe is also equipped with large direct-reading dials to the feed screws and a totally enclosed, automatically lubricated apron, with single-lever selection of the desired feed motion and a choice of coarse or fine feed to each motion.

2. Fixing Tool for Brick and Concrete. Details are contained in an illustrated 6-page brochure of an ingenious tool and accessories for fixing nails and screws in masonry, quickly and economically. The tool operates without cartridges or similar means, a few hammer blows on a driving pin being sufficient to drive nails or screw-bolts directly into brick or concrete in one quick operation.

3. Automatic Grinding Gauges. An interesting 12-page brochure contains details of a range of automatic grinding gauges, providing visible, independent, and automatic measurement during grinding operations. Futhermore, they are not influenced by vibration, temperature, or grinding-wheel wear, they can be fitted easily to any grinder, and the dial indicator provides exact readings with an accuracy of the order of ± 0·00008 in. Various models, depending on the application required, are available.

4. Parallel Roller-Bearing Axleboxes for Railways. In an extremely well-produced and illustrated 40-page brochure, details are given of roller-bearing axleboxes for railways, together with photographs of actual applications in locomotives and rolling-stock. Important features of these bearings include the ease with which the box can be removed, leaving only the inner race on the axle; their compact design and interchangeability; the elimination of any need for bearing adjustments, for screw threads on the axle, or for inner-race taper clamping sleeves; and the fact that no thrust is carried on journal bearings. Furthermore, tyre-turning can be effected without removal of the inner races.

5. Conveyors and Portable Stackers. A series of well-conceived and illustrated booklets gives details of a comprehensive range of conveyors and portable stackers. The first booklet (14 pages) deals with overhead monorail and other chain conveyors, with examples of types in common use, i.e., overhead monorail conveyors, swing tray elevators, and slat and chain conveyors for handling sacks, boxes, packages, etc. The second (6 pages) covers unit-construction flat-belt conveyors with numerous applications, while the third (14 pages) is concerned with portable stackers, designed specifically for handling boxes, sacks, packages, etc. and intended, not only for stacking, but also for the loading and unloading of vehicles.

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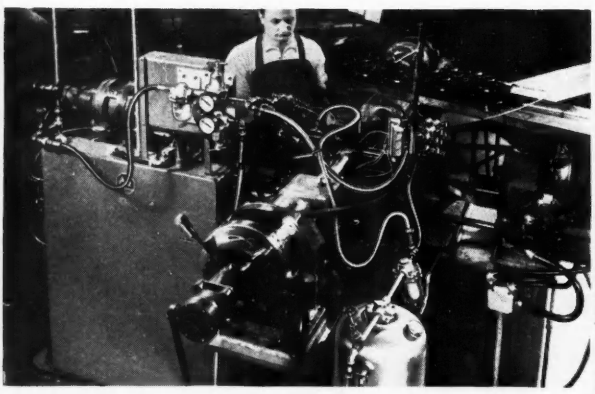

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